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AGRICULTURE RESEARCH SER
GLOBAL CHANGE RESEARCH PROGRAM

REPORT OF ARS GLOBAL CHANGE RESEARCH PLANNING WORKSHOP

BOISE, IDAHO JUNE 4-6, 1996

Northwest Watershed Research Center, B

United States
Department of
Agriculture

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GLOBAL CHANGE RESEARCH PROGRAM

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Northwest Watershed Research Center, Boise, Idaho

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PREFACE

PREFACE

The Agricultural Research Service (ARS), as the research arm of the United States Department of Agriculture, plays a leading role in global change research. The ARS Global Change Research Program (ARS/GCRP) , which is modeled after the United States Global Change Research Program (US/GCRP) developed by the National Science and Technology Council, comprises five research areas. The five research areas (each of which has a number of program elements) are:

1. Structure and Function research area designed to develop an understanding of how global change alters hydrologic and ecosystem processes.
2. Socioeconomic Driving Forces research area designed to observe, understand, and predict the forces that condition human response to the effects of global change.
3. Impacts and Adaption research area designed to observe, understand, and predict changes to human health, the structure and functioning of unmanaged ecological systems, and the productivity and structure of socioeconomic systems in response to single and multiple socioeconomic and environmental stresses of global change.
4. Mitigation and Enhancement research area divided into research and development, and demonstrations.
5. Assessments research area designed to assess the state of knowledge by providing mechanisms to perform national assessments of the effects of global change and to involve U.S. Scientific and technical communities in international assessments of the effects of global change.

The goals of the ARS/GCRP are to develop an understanding of the effects of global change on U.S. agriculture and to provide scientific information on which policies and decisions at local, regional, and national levels can be made for sustaining an abundant, nutritious, inexpensive food and fiber supply while maintaining a healthy, environment and a natural resource base.

This report contains a summary of the ARS Global Change Research Planning Workshop held in Boise, Idaho on June 4-6, 1996. The three day workshop was designed to facilitate the transfer of technology and foster interactive research between the three working groups of the ARS Global Change Research Program. The ARS/GCRP work groups (biogeochemical systems, ecosystem dynamics, and hydrology and climate) meet about every 2 years to coordinate research efforts and identify high priority research areas for future emphasis.

The program and accomplishments reported here are the result of significant efforts by many ARS scientists and administrators. Leadership and program coordination have been provided by J. Van Schilfgaarde, D. Bucks, D. Farrell, H. Mayeux, P. Sims, B. Acock, A. Rango, K. Cooley and R. Follett

ARS GLOBAL CHANGE RESEARCH PLANNING WORKSHOP PROGRAM

ARS GLOBAL CHANGE RESEARCH PLANNING WORKSHOP

June 4-6, 1996 Boise, Idaho

Tuesday June 4

8:00	Introductions and Purposes	Rango
8:05	Local Arrangements and Announcements	Cooley
8:10	Welcome	Vick Slaughter
8:30	Program Development	Bucks
8:50	USDA Global Change Program--The Future	Evans
9:10	ARS Global Change Program--The Future	Mayeux
9:30	Summary of Integrated Projects Begun in FY95	
	a. Soil Carbon Sequestration under Elevated CO2 Rates and Processes.	Hyrum Johnson
	b. "FACE Project Status: Wheat Productivity and Energy and Water Balances"	Bruce Kimball
10:10	Break	
10:40	Continue Summary Reports.	
	c. Verification of Water, Energy & Carbon Balance Models at the Canopy Scale.	Bill Kustas and Gerald Flerchinger
	d. A progress Report on the SALSA (Semi-Arid Land-Surface-Atmosphere) Program.	Dave Goodrich and Russell Scott
11:20	Status of the ARS Rangeland Carbon Balance-CO2 Flux Network	Mayeux
11:40	Announcements---Lunch	
1:00	Outline of plan for distributing temporary Global Change Funds for FY97, 98 and Guidelines for Proposal Submission	Mayeux

1:20	Concurrent Sessions for Within Group Program Development--Progress Reports	
	Biogeochemical	Follett
	Climate and Hydrology	Rango/Cooley
	Ecosystems	Acock
2:45	Joint Break	
3:15	Resume Concurrent Sessions	
5:00	Adjourn--Dinner of Northwest Cuisine	

Wednesday June 5

08:00	Tour of ARS Offices, and Laboratory Projects
09:30	Travel to Reynolds Creek Experimental Watershed
	Lunch
1:00	Tour of Reynolds Creek Experimental Watershed
5:00	Return to Boise

Thursday June 6

08:00	Resume Concurrent Sessions--Identification of High Priority Research for next year.	
09:45	Joint Break	
10:15	Resume Concurrent Sessions	
12:00	Lunch	
1:15	Joint Session	
1:20	Report from Ecosystems Group	Acock
1:40	Report from Climate and Hydrology Group	Cooley-Rango
2:00	Report from Biogeochemical Group	Follett
2:20	Break	
2:45	Discussion of Joint Research--Future Directions	Mayeux
3:00	Discussion on Next Meeting and Symposium	Rango
	a. Site and date	
	b. Poster Session	
3:30	Concluding Remarks	Bucks
4:30	Adjourn	

ARS Global Change and Hydrology Meeting
June 4-6, 1995 Boise, ID

Tuesday, June 4:

1:15 pm	Opening Remarks and Introduction	Rango, Cooley
	Location Progress Reports and Plans	
1:30 pm	Boise	
2:15 pm	Temple	
2:35 pm	Beltsville	
3:20 pm	BREAK	
3:40 pm	Tucson	
4:25 pm	Durant	
4:45 pm	Ft. Collins	
5:05 pm	ADJOURN	

Thursday, June 6:

8:00 am	Other Group Reports	
8:45 am	EPRI Progress	Cooley, Moran
9:15 am	Report from Dave Farrell - Science and Political Priorities	Farrell
9:45 am	BREAK	
10:15 am	Guidance from NPS on Global Change Priorities	Mayeux
10:45 am	Discussion of Global Change Program Issues	
	Cooperative Projects Between Hydrology Locations	
	Status of Large Scale Experiments	
	Other Issues of Interest and Goals for Next Year, i.e., High Priority Research	
	1997 or 1998 Global Change Symposium	
	Location and Time for Next Meeting	
12:00 Noon	LUNCH	

LIST OF ATTENDEES

ARS GLOBAL CHANGE WORKSHOP
Boise, Idaho June 4-6, 1996
List of Attendies

Basil Acock
L.H. Allen, Jr.
Ray Angell
Jim Bonta
James Bradford
Dale Bucks
James Bunce
Mike Burgess
Keith Cooley
Donn DeCoursey
John Doran
William Emmerich
Don Erbach
Gary Evans
David Farrell
Virginia Ferreira
Gerald Flerchinger
Ronald Follett
Al Frank
Jurgen Garbrecht
David Goodrich
Marshall Haferkamp
Clayton Hanson
Stuart Hardegree
Lowery Harper
Gary Heathman
Gordon Hutchinson
Greg Johnson
Hyrum Johnson
Tim Keefer
William Kemp
Bruce Kimball
Jim Kiniry
William Kustas
Herman Mayeux
Joe Miller
Ludmila Pachepsky
Fred Pierson
Wayne Polley
Kenneth Potter
Al Rango
Clarence Richardson
Reza Savabi
Jerry Schuman
Mark Seyfried
Marvin Shaffer
Ronald Sharpe
Phillip Sims
Charles Slaughter
Patrick Starks
Charles Tischler
Allen Torbert
Ken Vick
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Ross Wight
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X	X	X	WHITMAN	CAROL	USDA Global Change	Rm2M08 Annex Bg 300 12th St. SW	Washington DC	20250	202-401-3804	202-401-3812
	X		WILLIAMS	JIMMY	USDA-ARS-SPA	808 E Blackland Rd	Temple, TX	76502	817-770-6508	817-770-6561
	X		WILLIAMS	ROBERT	USDA-ARS-SPA	7207 W. Cheyenne	El Reno, OK	73036	405-262-5291	405-262-0133
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INVITED PAPER BY DAVID FARRELL, NPS

Global Change Science and Policy Issues

The topic that I was asked to address at this workshop has several scientific and political facets. Unfortunately, I will not be able to do justice to the many issues that impact on the science and politics of global change, nor to the many scientists who have contributed to the literature on global change. In searching through the archives of the Library of Congress for issues that might be of interest to this audience, I was confronted with the challenge of choosing from a list of 783 entries under the heading "Climatic Change". Interestingly, more than half the climate change references in the library were published in the 1990s. Clearly, there is still substantial general public, media, political, and scientific interest in the economic and societal consequences of global change.

Hearings on global change are held every year by Congressional committees, and in the interests of time, I will dwell only on some of the highlights of the legislative information. There is still a good deal of skepticism in some of the Congressional committees on the merits of the scientific agenda that has been developed by the Intergovernmental Panel on Climate Change (IPCC). In his testimony before the Senate Committee on October 26, 1994, Robert Watson, Associate Director for the Environment, Office of Science and Technology Policy, presented the following activities related to agriculture, water resources, and resource use and management that would benefit from the Administration's global change research program:

"***Agriculture:*** seasonal and year-to-year climate forecasts to support crop selection, planting, harvesting, and investment decisions; anticipation of extreme weather events; and prediction of regional changes in climate to support the development of adaptive management techniques.

Water Resources: regional allocation decisions; anticipation of and preparation for droughts and floods; long-term planning and design of capital investments (e.g. dams); and the development of adaptive strategies.

Resource Use and Management: long-term planning for managed ecosystems; management decisions for renewable resources and vulnerable ecosystems; and demonstration techniques and strategies for sustainable development."

Other global change scientists who participated in these hearings included: Richard Lindzen, Sloan Professor of Meteorology at the Massachusetts Institute of Technology, Stephen Schwartz, Senior Scientist at the Brookhaven National Laboratory, and Judith Lean, Research Physicist at the Naval Research laboratory. Lindzen was concerned about the lack of a scientific basis for some of the projections that have been made for global change, such as the increased frequency and severity of extreme weather events. He was also troubled by the limited research that had been done to evaluate the effects of changes in cloud cover and water vapor. Lean's testimony focused on the

extent to which changes in solar radiation may be responsible for the observed changes in global temperature. Lean concluded that the contribution to the radiation balance by changes in solar radiation are unlikely to be more than 30 percent of the contribution from greenhouse gases.

Another source of information on the scientific and political issues related to global change is the 1993 Report by the Office of Technology Assessment (OTA) entitled "Preparing for an Uncertain Climate." Three committees of Congress asked OTA to help them think about the problems associated with potential climate change. The question that they posed to OTA was "How can the United States set prudent policy, given that we do not know for certain what the climate will be?" OTA decided to respond to this Congressional request by attempting to address the following three questions:

1. ***"What is at risk over what timeframes?*** Which natural ecological systems and managed natural resource systems are at risk from climate change? How do the lead times needed for human interventions in these systems vary?"

2. ***"How can we best plan for an uncertain future?*** When and how should decision makers consider the uncertain effects of a changing climate as they plan the future management of natural and managed systems in the United States? What criteria should be used?"

3. ***"Will we have answers when we need them?*** Does the current U.S. Global change Research Program (USGCRP) reflect the short- and long-term needs of decision makers? Will it provide information about rates of climate change, the potential for "surprise" effects on different systems, potential strategies for making systems more resilient in the face of uncertain climate change, and adapting to the changes that may occur?"

Issues that the participants in this OTA study had to contend with were: "Given the potentially long delays until the onset of significant change, reacting to climate change as it occurs may seem more practical than undertaking anticipatory measures. Why adopt a policy today to adapt to a climate change that may not occur, for which there is significant uncertainty about regional impacts, and for which the benefits of the anticipatory measures may not be seen for decades?" There was also concern among many of the participants about the merits of a major societal initiative because the "Effort put into the measures could well be wasted. Furthermore, future generations may have more sophisticated technologies and greater wealth that can be used for adaptation." As a result of these and related concerns, OTA decided to limit its examination of the global change issues to those that might have scientific and political credibility and broad community support. The OTA report focuses on areas where: (1) the costs of climate change may be very high, such as floods

resulting in deaths and major property damage; (2) the impacts of climate change may be irreversible, such as species extinction or loss of valuable ecosystems; (3) the validity of long-term decisions made today may be affected by climate change, such as coastal and agricultural developments in climate sensitive areas that may exacerbate natural disasters; and (4) preparing for catastrophic events is already warranted, such as droughts, floods, and fires.

The OTA report covers six major natural or managed resource systems namely: coastal areas, water resources, agriculture, wetlands, preserves, and forests. The three systems that will be the focus for my discussions are: water resources, agriculture, and wetlands. The climate change problem related to water resources was framed in the context of: changes in water availability that would exacerbate the stress on already stressed systems, and changes in the frequency, duration, or severity of floods and droughts that would increase the economic and social costs of these natural hazards. The most vulnerable areas were identified as: those areas which were already experiencing high levels of stress on available water supplies, such as the southwest and Florida; areas where because of urban and industrial development the competition for water and damage from natural hazards can be expected to increase, and the central areas of the mainland which many of the scientists expect to become hotter and drier. The rationale for selecting these water resources problems and areas was the promotion of national policies that would not only prepare the nation for a less certain future climate, but also have value now by improving the nation's ability to cope more effectively with the economic impacts of droughts and floods.

The OTA report lists a number of policy options for improving the management of water supplies, managing the societal costs of droughts and floods, and incorporating structural improvements in research and development projects. Several of the policy options are targeted toward an improvement in the operational efficiencies of federal programs, and better integration and coordination of federal and State programs. The following is a list of the policy options contained in the OTA report:

1. Resurrect the former Water Resources Council or create a similar high-level coordinating body. (The Council exists legislatively but is unfunded).
2. Promote the reestablishment and strengthening of Federal-State river basin commissions as another way to improve coordination among agencies.
3. Require the Army Corps of Engineers and the Bureau of Reclamation to undertake periodic audits to improve operational efficiency.
4. Enhance the ability of the Army Corps of Engineers and the Bureau of Reclamation to modify operations of projects to meet changing conditions.
5. Tie funding of new Federal water projects to adoption of improved water management practices by the States.

6. Increase funding for the development of new analytical tools in system analysis studies.
7. Create an interagency drought task force with the authority to develop a national drought policy and plan.
8. Create a national flood assessment board to consist of representatives of Federal, State, and local agencies and the private sector.
9. Direct the National Flood Insurance Program to base risk calculations on anticipated development, rather than on current development.
10. Require that the potential for climate change be considered in the design of new structures or the rehabilitation of old ones.
11. Appropriate funds for wastewater reclamation, desalination, and other water supply research.

According to the OTA, the first steps of a national water resources strategy should be to: improve extreme-event management, promote basin-wide management of reservoirs, promote the marketing of water, promote the use of new analytical tools for water modeling and forecasting, and promote water demand management through water conservation and water use efficiency.

The climate change problems associated with agriculture are identified as: potential changes in the productivity of crop and livestock operations, and changes in the regional distribution and intensity of farming as the result of responses to commodity markets. Primary concerns of OTA, from the standpoint of the potential vulnerability of agriculture, are the long-term productivity and competitiveness of the U.S. agricultural production system, and the risk that consumers may face high food costs if the process of adaptation to climate change is slowed. According to the OTA report, the first steps of a national agricultural strategy should be to: revise commodity support programs to increase flexibility in crop acreages for specific commodities by allowing farmers to switch crops without penalty, modify disaster assistance programs in a way that would encourage farmers to reduce their exposure to climate risks, and enhance the agricultural technology base through the development and wider use of information technologies and computer-supported farm management tools.

The primary problem that was identified for wetlands is the potential for climate change to accelerate the loss of wetlands. The major policy option proposed in the OTA report is more support for long-term research and monitoring on the impacts of climate change on wetlands with specific areas of investigation identified as:

1. Establishing a baseline of wetland conditions nationwide and a long-term monitoring network to document rates and types of change.
2. Assessing how wetlands have already been altered in areas where the water

regime has changed in ways similar to those predicted from climate change.
3. Determining water needs for healthy wetlands and the hydrological connections between wetlands and groundwater.
4. Evaluating salt movement through estuaries, coastal aquifers, and inland surface water and groundwater systems.
5. Researching the adaptability of key wetland species (plants and animals).
6. Assessing how extreme events, such as droughts and floods, affect the functioning of wetlands, and
7. Developing and evaluating restoration and creation techniques.

In a broader context, the OTA report supports policy options that would promote: (1) research activities that are sufficiently broad in scope to involve physical, biological, and social scientists, (2) better integration of research results across disciplines, and (3) more effective communication of results back to the research community, policy makers, and decision makers. Furthermore, with respect to ecosystems research and natural resources planning, the report calls for: a review and evaluation of "how much long-term ecosystem research relevant to climate change, biodiversity, and other long-term problems is underway"; the identification of "important gaps in ecological research"; and the promotion of "research on monitoring and managing natural resources as a key component of a broadened global change research program."

The Canadian Climate Center has published a series of articles in "Climate Change Digest" relating to global climate change. Some of these reports are targeted toward agriculture and natural resources problems, others examine the implications of climate change on downhill skiing, tourism and recreation, boreal forests, and coastal communities. Because of the similarities of climate and terrain in Western Canada and the Pacific Northwest States, there would appear to be opportunities for collaborating on problems of mutual benefit to both countries. McBean et al. (1992) conducted a review of climate change models and the projected impacts on the hydrology of British Columbia. Wintertime rainfall was projected to increase by about 5mm per day with smaller changes and possibly lower precipitation in summer. The authors conclude that a heirarchy of hydrologic models will be required to simulate the diverse hydrologic regions of British Columbia. The Cnadian Climate Center has developed a high-resolution model, which the authors claim more accurately simulates present climate because of some major modifications. This report supports the widely held position that the hydrology components of the general circulation models (GCMs) are inadequate. The authors also claim a strong revival of initerest in water balance models, primarily because of the compatibility of these simple models with the output of GCMs. The report includes the following research recommendations:

1. Improve the spatial resolution of GCMs.
2. Improve the knowledge base of present climates.
3. Develop regional hydrologic models adapable to the terrain.
4. Develop models for evapotrabnspiration, soil moisture and runoff.
5. Model climate/fisheries interactions from known relationships.

A number of global change scientists, such as Bradley and Jones (1992) argue that because the effects of human activities on climate are not readily separable from the effects of natural forcing factors, and that until these factors are better understood, there is little prospect of either correctly interpreting the available meteorological and climate data, or projecting the effects of greenhouse gases on future climates. The publication focuses on documenting climate change during the last 500 years, and encourages the use of non-instrumented records to extend the quite limited meteorological data that is available. The authors identify sources of historical paleoclimatic information such as: ancient inscriptions, chronicles, government records, documentary records and quasi-scientific writings. Dendroclimatology is also promoted as having a major potential for reconstructing paleoclimatic records, and caveats for using this technique are given. The report provides a number of references to work that has successfully used documentary evidence and dendroclimatology to reconstruct temperature and precipitation records.

One of the more informative, non-theoretical documents on climate change is the book by Ian D. Whyte of Lancaster University, entitled "Climatic Change and Human Society", which was published in 1995. The book traces the history of scientific efforts linking human activities with changes in the Earth's climate. Whyte credits the Swedish scientist, Svante Arrhenius, with being the first to attempt to link land surface temperatures with carbon dioxide concentrations in the atmosphere. In 1895 Arrhenius attempted to explain the occurrence of ice ages on the basis of changes in atmospheric concentrations of carbon dioxide. Whyte also credits the English scientist, G. S. Callender, with being the first to link carbon dioxide emmissions into the atmosphere from human activities with the warming that occurred in the early decades of this century. Callender reported on this work in 1938. The International Geophysical Year of 1957, saw the start of systematic monitoring of atmospheric carbon dioxide, which ultimately resulted in the surge of scientific and public sector interest. Whyte draws attention in his book to the backlash that has taken place as a result of the extravagant claims that have been promoted by some scientists and headline seeking reporters for the effects of global warming on temperature and sea level rises in the next century. He refers to a 1995 report, published in the Sunday Times, claiming that the London Meteorological Office had decided that global warming was a myth. In fact, the cited report merely stated that the rate of warming would be slower than had been originally projected.

A few specialists in public policy, for example Brunner (1996), question the sustainability of the current global change program because they believe that continued public support is unlikely unless the information generated by the program is usable by policymakers. In establishing a basis for his concern, Brunner refers to a 1994 article in the Economist which warns that "A global change science that prefers fiddling with ever more complex number-crunching models to the fuzzier assessments of human risks and impacts will forget about saving the planet and lose its political support." An important perspective that Brunner brings to the successful integration of science and policy is that the context in which the value and relevance of science is assessed includes its contribution to critical social factors, such as "declining standards of living in the lower and middle classes, persistently high federal budget deficits and international trade deficits, and the end of the cold war." He and many others are convinced that science and technology will not be well received unless they are perceived as serving the public good. In making his point that these demands of society are not new, he quotes from a book published by Alvin Weinberg in 1967, "It is quite conceivable that our society will tire of devoting so much of its wealth to science, especially if the implied promises held out when big projects are launched do not materialize." Robert Fleagle (1994) is critical of the absence of clear leadership on global environmental problems, and suggests that the efforts on issues such as global environmental change may prove futile "unless the problems of world population and economic development are addressed at the same time as the environmental problems".

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AREAS OF PRIORITY RESEARCH AND IDEAS FOR PROGRAM IMPROVEMENT

AREAS OF PRIORITY RESEARCH AND IDEAS FOR PROGRAM IMPROVEMENT

Biogeochemical Systems Group

1. Integrate increasing knowledge of the bidirectional interactions between terrestrial ecosystems and the atmosphere to facilitate its application to questions such as nutrient-use efficiencies and management effects in sustainable systems across multiple time and space scales.

2. Spatial and temporal integration of projected soil gas exchange, carbon sequestration, and nutrient/waste management across fields, farms, and regions as a function of soil, climate, and management.

3. The interactions and understanding of the processes and quantification of amounts of greenhouse gas fluxes from various agricultural landscapes across temporal and spatial scales.

4. Determination of the effect of CO2 concentration and other climate change factors on the carbon and nitrogen flow processes from atmospheric to plant to soil systems, and respiration processes involved in sequestration of soil carbon.

5. Assess carbon storage in relation to processes--organic and inorganic forms. Find and evaluate available data and fill information gaps.

6. Land management effects on soil organic carbon and total soil nitrogen--fluxes and cycling (ex. Tillage, CRP, grazing systems, fire, etc.).

Ecosystem Dynamics Group

1. There needs to be more interaction between the three working groups, although the group structure is convenient for breakout sessions where scientists with similar interests can have free discussion

2. Another type of structure may be to choose several seminar topics and have folks report their work relevant to those topics.

3. Research not related to any of the chosen topics could be reported through simple posters, i.e. nothing fancy or requiring a lot of work.

Hydrology and Climate Group

1. The relationship between climate, environment and vegetation types is not well understood, but has a tremendous impact on the productivity and water balance of a watershed. We need to know the interactions between climate, biology, vegetation and the landscape.

2. We need to develop modeling approaches that deal with hydrologic and physical processes and their relationships across a range of scales.

3. We need to update weather models to be more relevant to climate changes.

4. We need better linkage to other groups. Emphasize problems not disciplines.

5. We need to update the Tasks listed in Appendix A--the proposal was to do this on a unit basis by June 22, 1996.

6. We need to more explicitly describe how or research is tied to Global Climate Change.

ANNUAL RESEARCH REPORTS

Characterizing the Areal and Temporal Variation on Snow Covered Area and Snow Water Equivalent under Changing Conditions during Accumulation and Ablation Periods

Principle Scientist: Keith R. Cooley
Cooperating Scientists: Martin Searcy and Peter Palmer
ARS GCRP: Res Area: I; Prog. Element: I; Objs. 1; Task: 1.
CRIS Number: 13610

Problem: Snowmelt is affected by a number of site and meteorological factors that vary considerably and are accounted for in snowmelt models by using a variety of simplifications. These simplifications usually reduce the models' accuracy, and actual snowmelt data are seldom available for comparison or calibration.

Approach: Snow depth and density were measured on a 30 meter grid over a 64 Ha watershed to determine the variability of snow conditions. In addition, snowmelt collectors were installed under the snowpack in areas representing a variety of snow depths, densities and exposures. For comparative purposes snow accumulation and melt data were obtained from eight NRCS snow pillow sites in the large Boise basin of central Idaho.

Findings: Snow depth was found to vary from 0 to 8 meters or more over distances of only 30 meters, while density varied from 10 to 55 percent in the same distance. To show the effects of this variability on snowmelt, the range of conditions were divided into three categories based on depth or snow water equivalent (swe) which is typically related to depth, and exposure. The three categories were: 1)shallow snowpacks (114 to 225 mm swe) on south facing sites; 2) general snowcovered areas (330 to 850 mm swe) on a variety of exposures and aspects; and 3) deeper snowpacks (465 to 1520 mm swe) on north facing sites. In general maximum snowmelt rates were found to be 30 to 75 mm per day for the shallow packs, 50 to 80 mm per day for the general snowcovered areas, and 100 to 180 mm per day for the deeper snowpacks. The timing of snowmelt outfow also varied considerably. Melt started as early as January 5th in the shallow packs and ended as late as July 27 in the deeper packs. It is obvious that snowmelt models need to be able to account for at least the range of melt rates noted in this study, and that ways to describe and account for the snowpack variability observed must be incorporated.

Future Plans: Develop relationships between aerial photo's of snow coverage and snow depth measurements for describing snowpack variability for use in snowmelt models.

Publications: Cooley, K.R. Snowmelt characteristics under various conditions. Proceedings 64th Annual Meeting, Western Snow Conference. Bend, Oregon, April 15-18, 1996.

Cooley, K.R., M.L. Searcy, and P.L. Palmer. "MAKEPROF" An interactive program for making profiles to evaluate SNOTEL data. User's Manual. USDA-ARS/NRCS, 1995, Version 1.1. West NTC Bulletin No. W290-5-102, July 18, 1995.

INFILTRATION TEMPORAL & SPATIAL VARIABILITY OVER A RANGE OF SCALES

Principle Scientists: W.E. Emmerich
Cooperating Scientists:
ARS GCRP: I.A.1.3
CRIS Numbers: 5342-13610-005-00D

Problem: Surface runoff and infiltration are influenced by soil, flora and fauna, management practices, topography, and precipitation intensity. All these influences have temporal and spatial variability over a range of scales and the next generation of hydrologic models will have to account for these conditions.

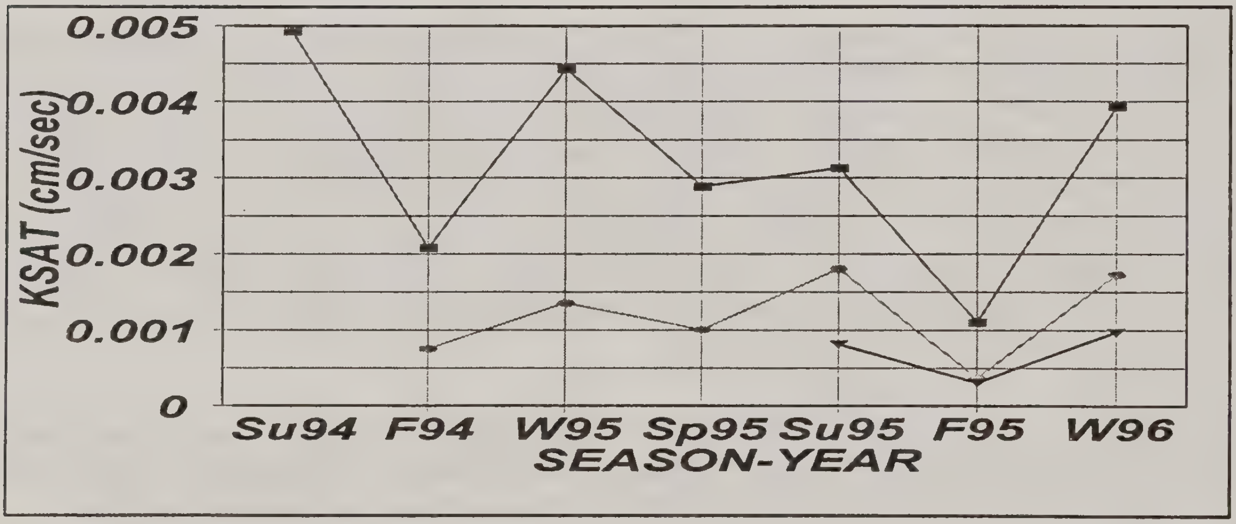
Approach: Disc permeameter measurement of soil conductivity and pore size will be made on one soil type seasonally for two years. The measurements will be made with and without soil erosion pavement present. The importance of erosion pavement on infiltration will be determined and the temporal and spatial variability.

Findings: One year of data has been collected. Preliminary results indicate the removal of erosion pavement slightly decreased the infiltration rate and soil pore size. Thus, the presence of the erosion pavement is important in maintaining soil structural integrity and higher infiltration rates. Additionally, the smallest pore sizes and lowest infiltration rates occurred in the fall. The seasonal differences are believed related to the impact of high intensity summer precipitation on the soil surface sealing it. The winter freeze thaw action then opens up the surface and the infiltration rate and pore size increase through the spring. The spatial variability of infiltration throughout the sampling period was found to be high, probably due to the small area over which each disc permeameter measurement was made.

Future Plans: A small (1 m^2) rainfall simulator with variable intensity is being developed to measure infiltration over a larger area and evaluate intensity factors. The simulator will be used to evaluate at a larger scale temporal and spatial variability on more soil and vegetation types.

Notes:

A change to a dryer climate would most likely result in the loss of vegetation protecting the soil from erosion. Accelerated erosion from a climate change or man's activities removing vegetation can lead to the formation of erosion pavement on soils containing rock fragments. Erosion pavement can influence the infiltration process. Disc permeameter infiltration measurements with six replications are being made seasonally for two years to evaluate temporal, spatial, and erosion pavement effects on infiltration. The infiltration measurements are being made with the erosion pavement in place, erosion pavement removed, pavement removed for one season, and removed for one year. Infiltration is showing temporal variability with generally higher infiltration in the winter and lowest in the fall. The removal of erosion pavement reduced infiltration. The removal of erosion pavement for one season or year reduced infiltration further and the reduction lasts for greater than one year. The large differences in replication measurements indicate the spatial variability in infiltration



Ksat for erosion pavement in place (--■--), erosion pavement removed previous season (--●--), and erosion pavement removed previous year (--▼--) for summer 1994 through winter 1996.

Nature of Spatial Variability as affected by Scale

Principle Scientist: Mark S. Seyfried
Cooperating Scientist: Brad Wilcox
ARS GCRP: Program Element I, Objective 1, Task 3
CRIS Numbers: 5362-13610-004

Problem: Physically-based hydrological models offer considerable potential for simulating the effects of global change over a wide range of scales. The primary advantage of physically-based models is that, because they are based on physical processes that are essentially time invariant, it is reasonable to extrapolate results in time. In addition, these models are usually spatially distributed, making it possible to simulate effects at different locations, rather than as some overall mean. Unfortunately, these models are almost impossible to parameterize rendering there application problematic. This is due largely to the large spatial variability of the parameters required. It may be that the point-scale models currently in use demand high resolution spatial data that are not needed for accurate depiction of processes of interest at larger scales.

Approach: We analyzed a variety of hydrological processes within the Reynolds Creek in terms of the spatial variability of hydrological responses and the scale of landscape features associated with those processes. We then collected soil-water samples over a broad range of scales to try to establish which scales contribute most of the variability.

Findings: We found that, in nature, different sources of variability in the same watershed can be described as either stochastic or deterministic depending on the scale. Therefore, it will not be possible, in general, to characterize watersheds in terms of a single deterministic length scale independent of scale and watershed properties. The deterministic length scale is logically linked to the scale of interactions that result from the sources of deterministic variability. In our case, shrubs, rock outcrops, snow drifts, topography and elevation. At modeling scales within the deterministic length scale, site-specific model parameterization is required because hydrologic response is sensitive to the distribution of site-specific characteristics. At larger scales, stochastic or homogeneous approaches may suffice, thus reducing model data requirements.

More specifically, with regards to soil-water content, we found that:

1. the spatial variability of soil-water content at meter scale is approximately equal to that at a small watershed scale provided a single series is involved,
2. the spatial variability of soil-water content is highly dependent on the average water content, and
3. stratification of spatial variability by soil series explains significant amounts of spatial variability.

Future Plans: We intend to use these results to modify an existing, point scale soil-water model to operate over relatively large (250 km^2) areas. This will be integrated with our remote sensing work.

Publications:

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Seyfried, M.S., and B.P. Wilcox. 1995. Scale and the nature of spatial variability: field examples and implications to hydrologic modeling. Water Resources Research 31:173-184.

Seyfried, M.S., and G.F. Flerchinger. 1995. Soil temperature and water content during runoff from frozen soil under seasonal snow. EOS 76, 46: F236.

Seyfried, M.S. and G. N. Flerchinger. 1996. Effects of Scale on Frozen Soil Runoff. To be presented at workshop on Scale Problems in Hydrology, June 17-20, 1996.

CHARACTERIZATION OF RAINFALL VARIABILITY AND ITS IMPACT ON RUNOFF OVER A RANGE OF SCALES

Principle Scientists: D.C. Goodrich, L.J. Lane
Cooperating Scientists: J.M. Faurès (FAO)
ARS GCRP: I.A.1.3, I.A.4.1, I.A.5.1
CRIS Numbers: 5342-13610-005-00D

Problem: Rainfall, particularly in semiarid regions can exhibit extreme spatial variability. This has been recognized at larger spatial scales (>several kilometers) but has not been tested at small watershed scales where the assumption of uniform rainfall is typically made. At larger scales (~100 km^2) a thorough analysis of the geometric properties of air mass thunderstorm cells, both during a storm and for storm totals with overlapping antecedent rainfall, has not been carried out. This is required to better understand the variability of rainfall and its impacts on runoff prediction.

Approach: At the small scale, a 4.4 hectare watershed at Walnut Gulch was instrumented with 10 recording and 50 nonrecording raingages. Detailed observations of rainfall, runoff and soil moisture were made over a summer (rainfall) season at Walnut Gulch. Over the entire Walnut Gulch watershed, 3-D rainfall field characteristics were computed for storm totals and as a function of time to define the peak intensity rainfall field. To accomplish this space-time interpolation, methods were evaluated to define rainfall surfaces from the 85 raingages for 302 summer storms over three watersheds bridging a range of scales (WG11 - 6.3 sq. km., WG6 - 81 sq. km., WG1 - 150 sq. km.) and regression relationships were developed to relate storm properties and position to observed runoff.

Findings: The observations and analyses at the 4.4 ha watershed demonstrated that the common uniform rainfall assumption was not valid. Impacts of the rainfall variability on modeled runoff were substantial. Because small experimental watersheds with a single raingage are often used to verify many hydrologic models, this finding has important implications as error attributed to the model may actually result from spatial rainfall variation. At the larger scale, multiquadric interpolation was found to be superior to kriging for this application. It was found that basin attenuation of rainfall measured in terms of the peak in addition to volume outflow to inflow ratios increased with increasing watershed scale. Temporal attenuation, namely a longer lag between storm peak and runoff peak also increased with basin scale as expected. Simple multivariate regression was used to relate various storm characteristic measures to runoff. It was found that the volume of rainfall from the storm core (intensities > 25 mm/hr) explained more variance than any of the other postulated measures.

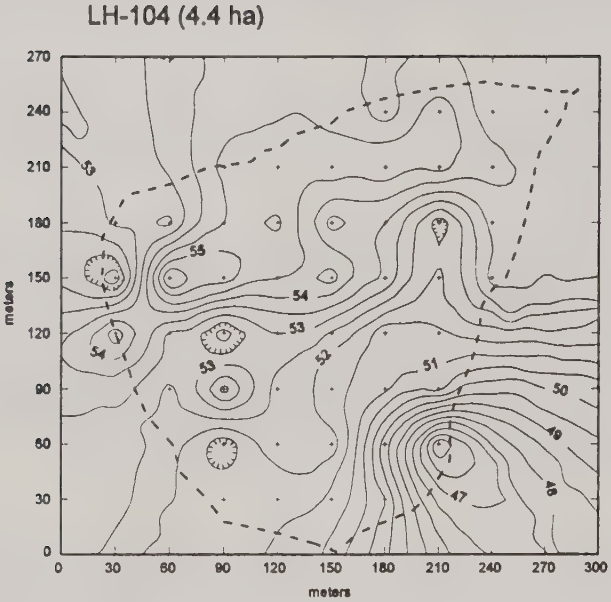
Future plans: In cooperation with the Nat. Weather Service, Walnut Gulch rainfall observations will be used to validate radar-rainfall relationships from the newly installed NEXRAD radar.

Publications:
Syed, K. H., 1994. Spatial storm characteristics and basin response. M.S. Thesis, Dept. of Hydrology and Water Resources, Univ. of Arizona, Tucson, AZ, 261 pp.

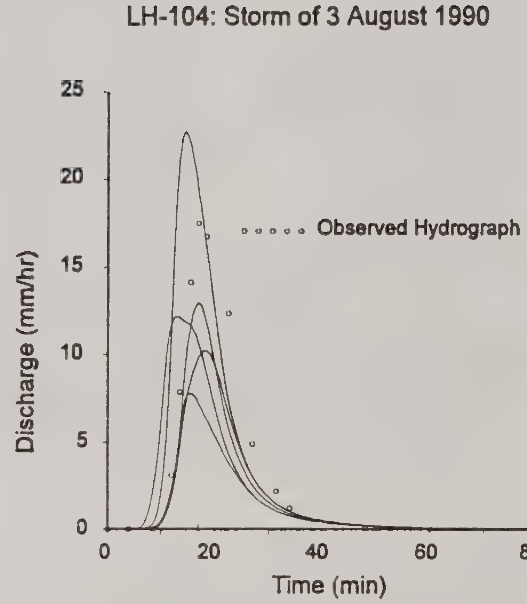
Goodrich, D. C., Faurès, J. M., Woolhiser, D. A., Lane, L. J., and Sorooshian, S., 1995. Measurement and analysis of small-scale convective storm rainfall variability. *J. of Hydrology*,173(1995):283-308.

Faurès, J. M., Goodrich, D. C., Woolhiser, D. A., and Sorooshian, S., 1995. Impact of small-scale

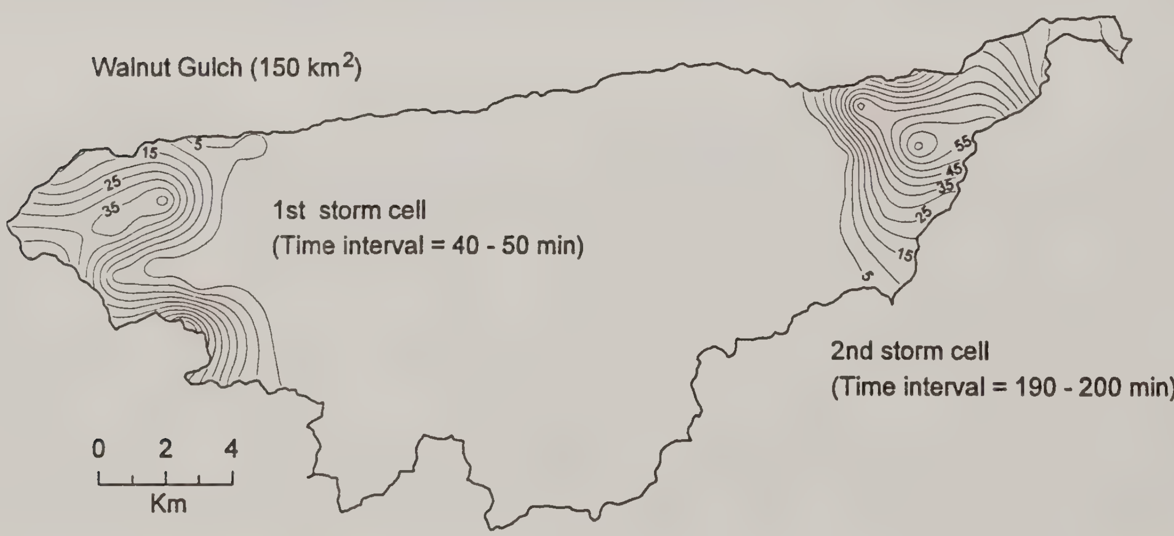
Notes:



1a. Total rainfall depth for the storm of 12 August 1990 (interpolation based on 55 raingages).



1b. Hydrographs modeled assuming spatially uniform rainfall from each of five recording raingages measuring the same storm.



1c. An example of significant large-scale, space-time variability of rainfall (storm of 30 July 1989).

Figure 1a. illustrates that an assumption of spatially uniform rainfall at the 5 ha scale is not valid; this was found to be true for 9 of 11 observed events. Ignoring rainfall variability at this scale can significantly effect modeled runoff estimates (Figure 1b.). At the much larger scale of Walnut Gulch (150 sq.km), temporal variability also becomes important (Figure 1c.). The properties of rainfall cells and their relation to runoff generation over a large number of storm events is being studied.

A UNIFORM VERSUS AN AGGREGATED WATER BALANCE OF A SEMI-ARID WATERSHED

Principle Scientists: G.N. Flerchinger, K.R. Cooley, C.L. Hanson, M.S. Seyfried and J.R. Wight

ARS GCRP: Research Area WR; Program Element I; Objective 1; Task 4

CRIS Numbers: 5362-13610

Problem:
Hydrologists have long struggled with the problem of how to account for spatial variability in precipitation, vegetation and soils. Particular attention has recently been focused on methodologies to aggregate areas together to evaluate the areal response of hydrologic processes.

Approach:
Two approaches to compute a water balance were compared for two years of data collected at the Upper Sheep Creek Watershed, a 26-ha semi-arid mountainous sub-basin within the Reynolds Creek Experimental Watershed in southwestern Idaho. The approaches included: a uniform approach in which the entire watershed was assumed homogeneous; and an approach in which a water balance was computed for each landscape unit, then aggregated together to compute an overall water balance for the watershed.

Findings:
In the aggregated approach, the watershed was divided into three distinct areas according to dominant soils and vegetation. Evapotranspiration was estimated using model simulations validated with measurements from Bowen ratio units. Soil water profiles, ground water levels and runoff measurements were taken to quantify changes in water storage and runoff. The water balance for the aggregated approach was within 1 and 50 mm, respectively for the two years, while the uniform approach was within 22 and 88 mm, respectively. The primary difference between the two approaches was how the precipitation and evapotranspiration were represented. The larger errors in the uniform approach were attributed to inaccurate estimates of evapotranspiration as a result of not being able to associate available soil water with areas of the watershed with more vegetation, leaf area and potential to transpire the water. The significance of the increased error using the uniform approach, which amounts to approximately 5% of the total precipitation input for either year, cannot be stated quantitatively, but depends on the particular application. For many applications, the increased effort required for the aggregated approach would not warrant the small increase in accuracy.

Future Plans:
A distributed model has been applied to the model, and preliminary work has been done for comparing the three approaches: uniform; aggregated; and distributed modeling of the watershed.

Publications:
Flerchinger, G.N., K.R. Cooley, C.L. Hanson, M.S. Seyfried and J.R. Wight. 1994. A lumped parameter water balance of a semi-arid watershed. Presented at Amer. Soc. of Agric. Engin. Summer Meeting, Kansas City, MO. Paper No. 94-2133. 18 p.

Flerchinger, G.N., K.R. Cooley, C.L. Hanson, M.S. Seyfried and J.R. Wight. 1996. A uniform versus an aggregated water balance of a semi-arid watershed. Hydrol. Proc. (In review)

SOIL MOISTURE FLUX AND HEAT TRANSFER PROCESSES AT DIFFERENT SCALES

Principle Scientists: Patrick Starks, Robert Williams
Cooperating Scientists: Laj Ahuja, Frank Schiebe
ARS GCRP: Res. Areas: I; Prog. Element: A; Obj.: 1; Task: 4
CRIS Numbers: 6220-13610-008-00D

Problem: Soil water content represents a significant water storage volume in the land hydrologic cycle and affects the partitioning of incoming solar radiation into latent heat (evapotranspiration) and sensible heat (air temperature), and, thus, is important to both the energy and mass balance approaches in the quantification of the hydrologic cycle. The role of surface soil moisture in this partitioning of solar radiation at a variety of scales and how spatial and temporal patterns of soil moisture are related to the physical and hydrologic properties of the soils is not well understood.

Approach: Measure the spatial and temporal variation of soil water and heat using 22 Soil Heat and Water Measurement Systems (SHAWMS) which are co-located with the existing ARS Micronet (meteorological stations) on the Little Washita River Watershed (LWRW). These data will also be used to address scaling issues related to soil heat and water.

Findings: Eleven of the planned 22 SHAWMS stations have been recently (end of May 1996) installed on the LWRW. Data from the incomplete SHAWMS network is undergoing preliminary analysis. However, data from the fully installed network is required before the spatial and temporal variability of the measured parameters and scaling issues can be adequately addressed.

Future Plans: Pending development and approval of El Reno research program: Finish installing the SHAWMS on the LWRW, perform in-situ calibration of the soil moisture sensors at each location, measure soil properties (profile measurements of soil water retention, bulk density, particle size distribution, texture, etc.) at each of the SHAWMS locations. Begin analysis of spatial and temporal variability of soil water content and heat flux from the fully installed and operational SHAWMS network. Develop scaling theory for describing hydraulic properties of varying soil types for integrating water and energy fluxes at different scales.

ABSTRACT

Title: Development of crop management models to simulate possible future climates and hydrologic regimes.

Principle Scientists: **Jim Kiniry**

Cooperating Scientists: **J.R. Williams**

ARS GCRP Res. Area I; Prog. Element A: Objective:1; Task 4

CRIS Numbers: 6206-13610-001-00D

Problem: Prediction of crop responses to climate changes, especially rainfall and temperature, depends on realistic crop simulations. Texas represents an area of extremes in temperature, relative humidity, and soil types. Many possible future scenarios for the Midwest are similar to the present climates experienced across Texas. Thus, Texas is an ideal model for testing simulation models for future climates.

Approach and Findings: We are studying two important systems for responses to climate. The first is row cropping of corn and sorghum. The other involves C4 grass systems, both with and without brush competition. We validated the ALMANAC model for corn from nine locations across the U.S. (Kiniry et al., 1996b) in TX, LA, five Midwestern states, NY, and MN. We are presently testing ALMANAC with corn and sorghum at four irrigated and five dryland sites in TX. These vary from warm humid locations in the Rio Grande valley and near the Gulf of Mexico to low humidity, high evaporative demand sites in northern TX and the High Plains. The model reasonably simulates yield of both corn and sorghum at these diverse sites. These data sets and the model and parameters are available to users to aid in development of additional data sets at other locations.

Work with C4 grasses, mesquite and eastern red cedar involves the development of parameters for leaf area index, radiation use efficiency, and partitioning. Three years of field results with the two woody species indicates conservative RUE values of 1.62 g per MJ intercepted PAR for mesquite and 1.60 for cedar After four years, LAI values were 1.25 for mesquite and 1.16 for cedar. Light extinction coefficients were 0.34 for mesquite and 0.37 for cedar. These values will greatly improve our ability to simulate grass/brush competition with ALMANAC. Our results in the field at Temple in 1995 with C4 grasses have shown a wide range of RUE values. Switchgrass has the highest RUE, sideoats grama the lowest, and big bluestem and eastern gamagrass intermediate values. Gas exchange measurements at representative heights in the leaf canopy show no relationship between CER and RUE for these species. We also studied potential rooting depth and partitioning to the roots. These values along with the LAI values and light extinction coefficients will greatly improve ALMANAC's ability to simulate these important grass species. Some of these parameters have already been incorporated into ALMANAC as shown in a multilocation validation study across Texas with switchgrass (Kiniry et al., 1996a.). In similar work, we developed plant parameters for grasses and crops in the Northern Great Plains for EPIC and validated the model in cooperation with Canadian researchers (Kiniry et al., 1995).

Future Plans: Our work continues on parameter improvement with mesquite, cedar, and the C4 grass species. We will also improve our parameters of cool season grasses.

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Dugas, W.A., D.C. Reicosky, and J.R. Kiniry. Chamber and micrometeorological measurements of CO_2 and H_2O fluxes for three C_4 grasslands. (accepted in Agric. For. Meteorol. Feb. 1996).

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Kiniry, J.R., J.R. Williams, R. L. Vanderlip, J. Atwood, D. Reicosky, J. A. Mulliken, W. J. Cox, H. J. Mascagni, Jr., S. E. Hollinger and W. J. Wiebold. 1996b. Evaluation of two maize models for nine U.S. locations (submitted to Agron. J.).

SIMULATING EVAPOTRANSPIRATION AND SURFACE ENERGY FLUXES ON SEMI-ARID RANGELANDS

Principle Scientists: G.N. Flerchinger,

Cooperating Scientists: C.L. Hanson, W.P Kustas, J.R. Wight, and M.A. Weltz

ARS GCRP: Research Area WR; Program Element I; Objective 1; Task 4
Research Area WR; Program Element I; Objective 3; Task 1

CRIS Numbers: 5362-13610

Problem:
Variability of energy and water fluxes across a landscape due to changes in soils and vegetation complicate efforts to quantify or predict energy and water exchange between the surface and the atmosphere. Current models do not adequately address the spatial variation across a landscape. Improved process-oriented models will enable better quantification of water and energy fluxes.

Approach:
Detailed simulations of the surface energy balance using the Simultaneous Heat and Water (SHAW) model were compared with measurements collected at the Reynolds Creek Experimental Watershed in Idaho and the Walnut Gulch Experimental Watershed in Arizona. Simulations were conducted for three vegetation types (low sagebrush, mountain big sagebrush and aspen) in Idaho and two vegetation types (grassland and creosote bush) in Arizona.

Findings:
Simulated diurnal variation in each of the surface energy balance components compared well with measured values for all sites. Measured and simulated ET for approximately 25 days of measurement at the Idaho sites were 41 and 44 mm, respectively, for the low sagebrush, 74 and 69 mm for the mountain big sagebrush and 85 and 89 mm for the aspen. Measured and simulated ET for 20 days of measurement at the Arizona sites were 66 and 48 mm for the creosote bush and 74 and 69 for the grass-dominated site. The variation in hourly simulated evapotranspiration accounted for by the model ranged from 56% for the creosote bush site in Arizona to 78% for the aspen site in Idaho. Canopy and soil surface temperature measurements were available at the Walnut Gulch sites. Canopy temperatures were simulated somewhat better at the relatively homogeneous grass-dominated site. Canopy leaf temperatures for the shrub-dominated site were consistently over predicted by 1.8°C compared to measured values. Soil surface temperatures were simulated quite well at both sites (mean bias error less than 0.9°C and model efficiency of 94%). The ability of the model to simulate canopy and surface temperature gives it the potential to be verified and periodically updated using satellite observations of radiometric surface temperature when extrapolating model-derived fluxes to other areas.

Future Plans:
Incorporation of the SHAW model into a distributed modeling framework will increase the utility of the model for application to landscape areas.

Publications:
Flerchinger, G.N., C.L. Hanson, W.P. Kustas and M.A. Weltz. 1996. Modeling Evapotranspiration on Semi-Arid Rangelands. In: Proceedings of the North American Water and Environment Congress '96. ASCE. (In press)

Flerchinger, G.N., J.M. Baker and E.J.A. Spaans. 1996. A Test Of The Radiative Energy Balance Of The Shaw Model For Snowcover. Hydrol. Proc. (In press)

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Flerchinger, G.N., C.L. Hanson and J.R. Wight. 1996. Modeling evapotranspiration and surface energy budgets across a watershed. Water Resour. Res. (In press)

Quantification of Spatially Distributed Fluxes with Remote Sensing

Principal Scientist:	William P. Kustas
Cooperating Scientists:	Tom J. Schmugge,Tom J. Jackson, Karen S. Humes
ARS GCRP:	Res. Areas: I; Prog. Elements: A; Objs.: 1; Tasks: 4, 5
	Res. Areas: I; Prog. Elements: A; Objs.: 2; Tasks: 1
	Res. Areas: I; Prog. Elements: A; Objs.: 3; Tasks: 4
	Res. Areas:V; Prog. Elements: A; Objs.:1; Tasks: 1
CRIS Numbers:	1270-13610-004-00D
	1270-13660-005-00D

Problem: In order to properly address effects of global climate change on the environment, energy exchanges between the terrestrial ecosystems and the atmosphere need to be evaluated over a range of temporal and spatial scales. Remote sensing is the only technology which has the capability to integrate land surface characteristics and processes with the atmosphere, but interpretation of remotely sensed information is complicated because the signal is affected by many surface properties, including atmospheric effects.

Approach: To better interpret the remote sensing data and evaluate its utility in models for computing spatially distributed surface fluxes, large scale multidisciplinary field experiments are being conducted in different climates and terrestrial ecosystems. In these experiments, remote sensing data from ground, aircraft and satellite sensors are collected in concert with meteorological and energy flux data, including upper atmospheric data.

Findings: The surface radiation balance, essential for quantifying terrestrial fluxes, can be estimated within 10% of measured values using remote sensing data. Remotely sensed surface temperature and reflectance data were successfully used in computing surface energy fluxes from local to regional scales. Passive microwave data were useful in mapping soil moisture and relative rates of evaporation over a whole basin. Remotely sensed data at a range of spatial resolutions were used with a land surface-atmosphere model to compute basin scale energy fluxes. The resolution of the remote sensing data did not significantly impact the basin-average fluxes computed by the model. Thus, it may be possible to monitor terrestrial fluxes for some ecosystems with existing operational satellites.

Future Plans: Develop and validate procedures for extrapolating surface fluxes from basin to regional scales using remotely sensed data in models simulating the interaction of terrestrial ecosystems with the atmosphere.

Publications:

Chanzy, A. and W. P. Kustas. 1995. Evapotranspiration monitoring over land surface using microwave radiometry. Proceedings of the ESA/NASA International Workshop on Passive Microwave Remote Sensing Research Related to Land-Atmosphere Interactions. (B. J. Choudhury, M. H. Kerr, E. G. Njoku and P. Pampaloni, Editors) pp 531-550.

Kustas, W. P., L. E. Hipps and K. S. Humes. 1995. Calculation of basin-scale surface fluxes by combining remotely sensed data and atmospheric properties in a semiarid landscape. Boundary-Layer Meteorology. 73:105-124.

Jackson, T. J., Le Vine, D. M., Swift, C. T., and Schmugge, T. J. 1995. Large scale mapping of soil moisture using the ESTAR passive microwave radiometer. Remote Sensing of Environment. 53:27-37.

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Carlson, T. N., R. R. Gillies, and T. J. Schmugge. 1995. An interpretation of methodologies for indirect measurement of soil water content. Agricultural and Forest Meteorology. 77: 191-205.

Kustas, W. P. and K. S. Humes. 1996. Variations in the surface energy balance for a semi-arid rangeland using remotely sensed data at different spatial resolutions. *The Scaling Issue in Hydrology* (Editors: J. B. Stewart, E. T. Engman, R. A. Feddes and Y. Kerr) Proceedings of the Scaling up Workshop, Institute of Hydrology, Wallingford UK. Published by John Wiley & Sons, Ltd. In Press.

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Humes, K. S., W. P. Kustas and D. C. Goodrich. 1996. Spatially-distributed sensible heat flux over a semiarid watershed Part I: Use of radiometric surface temperatures and a spatially uniform resistance. Journal of Applied Meteorology. In Press.

Kustas, W. P. and K. S. Humes. 1996. Spatially distributed sensible heat flux over a semi-arid watershed Part II: Use of a variable resistance approach with radiometric surface temperatures. Journal of Applied Meteorology. In Press.

COUPLING REMOTELY SENSED DATA TO A MESOSCALE ATMOSPHERIC MODEL

Principle Scientists: J.J. Toth, D.C. Goodrich, M.S. Moran, J. Qi
Cooperating Scientists: R. Avissar, A.F. Rahman, Electric Power Research Institute
ARS GCRP: I.A.1.4, I.A.1.5, I.A.1.7, I.A.3.1, I.A.4.4, I.D.1.5
CRIS Numbers: 5342-13000-003-03T via ARS/USGS/EPRI CRADA (new project, initiated 8/95)

Problem: Remotely sensed data can be used to estimate surface sensible and latent heat fluxes over broad regions. These fluxes are of concern for atmospheric global models as well as for agricultural purposes. Many existing flux-estimate techniques make inappropriate assumptions in areas of complex topography and sparse vegetation.

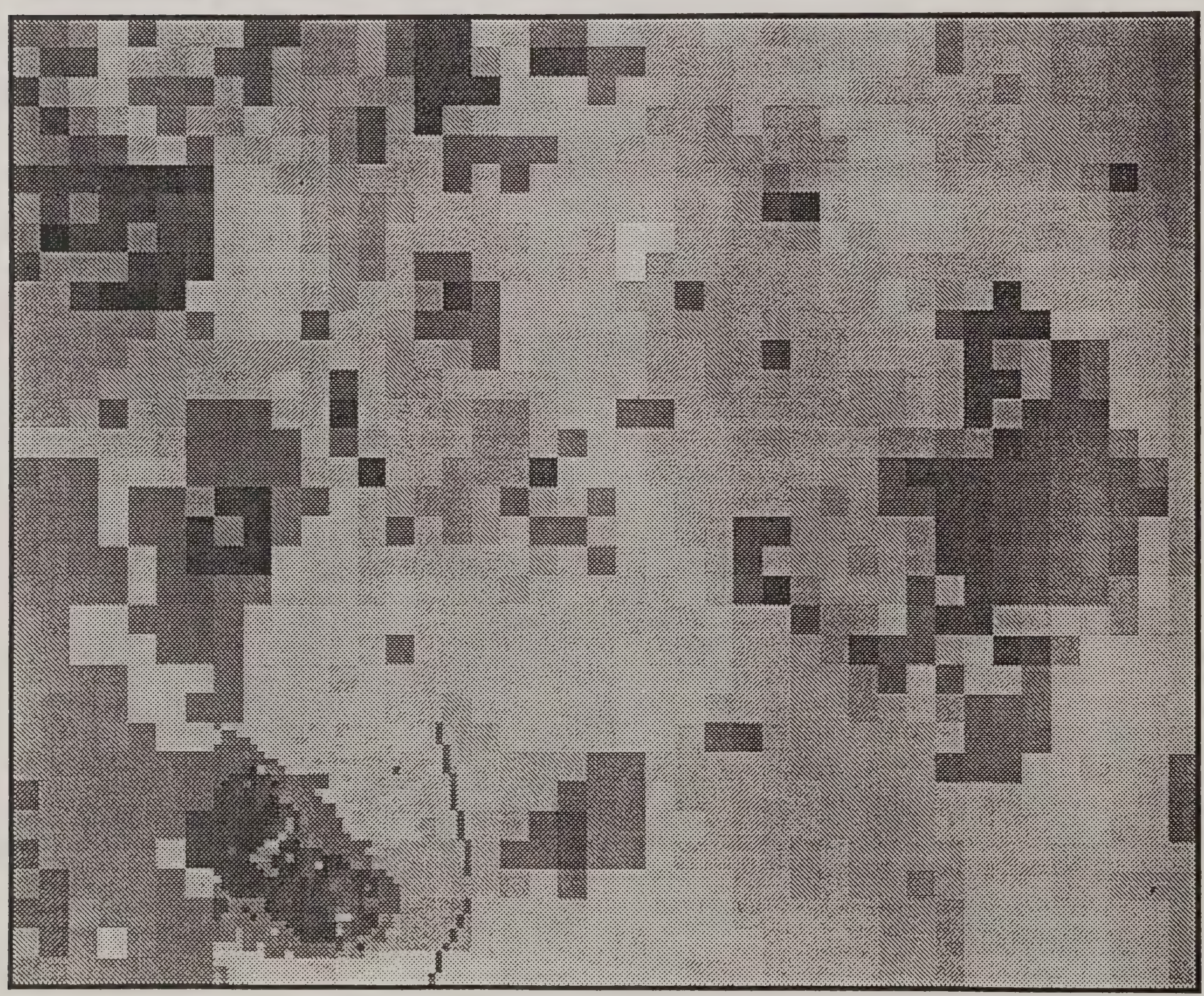
Approach: Remotely-sensed parameters were used to provide inputs to the RAMS (Regional Atmospheric Modeling System) model. Based on previous work, the most useful satellite data were assumed to be (1) the effective surface temperature and (2) the NDVI vegetation index. These were used to adjust the most critical inputs for the atmospheric model.

Findings: The effective surface temperature provides the clearest and most direct link between remote sensing inputs and model outputs. As a minimum requirement the surface parameterization in the model must produce surface temperatures consistent with the satellite data. The effective surface temperatures were calculated as a weighted average of the model's vegetation temperatures and bare soil temperatures. All temperatures were converted to potential values (i.e. adjusted to sea-level using a dry-adiabatic lapse rate). The critical model inputs having the most impact on the effective surface potential temperature were found to be (1) the fractional cover of vegetation and (2) the moisture availability. A combination of objective and subjective methods were used to obtain consistent surface temperatures. While recognizing that additional work will be needed to completely couple the remote sensing data with the model inputs, the model parameters appeared sufficiently accurate to proceed with preliminary simulations over the San Pedro basin in southeast Arizona and northern Mexico (the SALSA program). These simulations highlighted the importance of horizontal heterogeneities (mountains) in the atmosphere as well as at the surface. The mountains blocked and diverted the airflow, they became elevated heat sources, and they modified the turbulent mixing processes. Mountain effects were found to dominate cross-border land use differences. As an example, cross-border vegetation contrasts were placed in the model in order to investigate potential siting of field observations. During the mid to late morning hours circulations developed near the border that were clearly driven by the vegetation contrast. But by early afternoon heated air from an upstream mountain range moved across the border. This temperature contrast in the upper boundary layer gradually took control of the low- level circulation, in spite of continued land-surface thermal contrasts at the border. The SALSA program design will need to take into account such effects.

Future plans: The technique for coupling remotely sensed data with model input parameters needs to be refined so that it can be applied automatically without subjective adjustments. Consideration should be given to revising and simplifying the surface parameterization so that inputs are more directly connected to the available remotely-sensed data. The techniques developed in this project need to be documented and incorporated into the Modular Modeling System (MMS).

Notes:
This is RAMS model output for an area mostly over southeast Arizona, including the San Pedro. The Arizona-Mexico border is one coarse-grid cell above the bottom of the figure. The temperature within each grid square is a weighted average of the vegetation temperature and the bare soil temperature. Darker is colder. Temperatures are absolute and reduced to sea-level to compensate for elevation differences. Considering the relatively coarse (4-km) resolution over most of the area, there is reasonably good agreement with the Landsat thermal data. Over a portion of the San Pedro, including the Huachuca Mountains and part of the river, the resolution is increased to one kilometer. The bright horizontal band at the south end of the Huachucas results from a model-imposed reduction of the vegetation cover over Mexico.

Effective Potential Temperature



1700 UTC July 26, 1990

312 to 320 K

Regionalization of Storm Hyetographs

James Bonta, Virginia Ferreira, Clayton Hanson, Greg Johnson

ARS GRCP: I-A-1-5

CRIS Numbers:
3605-13000-003-00D (Coshocton)
40153-62050-13610-003 (Boise)
5402-61660-004-00D (Ft. Collins)

Problem: Short-time-increment precipitation inputs are needed for infiltration-based watershed models of hydrology, water quality, and erosion that can be used to evaluate the small-scale effects of global changes on hydrology, floods, crops, etc. Currently only measured data and artificial patterns of precipitation are used for these inputs. Limitations of these inputs include inflexible intensity variations, no measured record or short record lengths, and lack of a link to changes in climate as predicted by climate models. Consequently, a method for synthesizing short-time-increment precipitation data with appropriate statistical properties under different climate scenarios is needed.

Approach: Investigate methods for estimating time between storms (TBS) that separate storms in a measured record, and determine the parameters of the resulting frequency distributions as they vary regionally and under different climates. Relate these parameters to average monthly precipitation, and compare Huff curves developed from the TBS over different regions and climatic areas. Develop a method for comparing Huff curves developed under different assumptions.

Newly initiated coordination between the Ft. Collins and Coshocton and Boise locations led to a 4-month visit to Ft. Collins by Dr. Bonta for expanded work on regionalization of Huff curves to include stochastic simulation of rain storms. This led to a change in approach that has significant benefits for both regionalization and stochastic simulation objectives.

Findings: Maps were made of all locations in all US states, of National Weather Service rain gages which have 20 or more years of record, corrected for percent of missing record, for 15-min, hourly, and daily data. The availability of data sets is important for guiding regionalization efforts. Hourly data were found to be more well-distributed than 15-min data, and 24-hr data covered the US well. Consequently, hourly data will most likely be used for further short-time interval studies. Programs were written to determine monthly total precipitation from daily values, to extract data, and to develop Huff curves. Data from Reynolds Creek watershed are being reduced for use in the TBS and Huff-curve programs, to study elevation effects on storm characteristics. A program was modified to more comprehensively examine the TBS for purposes of stochastic simulation, and for an objective method for determining TBS and developing Huff curves. The capabilities include determination of TBS as a function of months of occurrence, years, sampling interval of the data, and method of determination. The original method of TBS determination utilized the exponential distribution with undetermined TBS less

than the critical TBS. The method is being redeveloped using a lower bound on the exponential distribution, and other methods are being evaluated for determining when the distribution is exponential. Preliminary runs were made with entire years of record and sampling intervals of 15-min, 60-min, and breakpoint rainfall for some Colorado and Ohio precipitation stations. The results were plotted in distributional forms, and as graphs of TBS vs. corresponding beginning and ending months. The latter plots show the regionality, data problems, and needs associated with developing a regionally-based method for stochastically generating the TBS. Results suggest that the exponential distribution is appropriate for use for stochastic simulation of dry periods between storms.

Preliminary analysis of beginning and ending months show that the TBS must include at least two months, and sometimes three or four, but regionality is suggested. These results indicate that monthly determination of TBS is necessary, using fixed starting months and varying ending months. Sampling intervals of 15- and 60-min show little differences in TBS values, making the more available hourly data useful for project purposes. Break-point data show some disparities that must be investigated.

Future Plans: The techniques for estimation of TBS will be further explored, and a method developed for the dual purpose of stochastic generation and Huff-curve development. This will allow characterization of the dry-period durations within storms that are less than TBS, and the statistical description of storm occurrences over time. The method will include the necessary components for regionalized TBS inputs, and for regionalized inputs for Huff curves, including the evaluation of variations due to elevation and spatial differences on Reynolds Creek. Factors important for regionalization of Huff curves will be investigated beyond previous published studies. Other aspects of stochastic generation of storm hyetographs will be investigated. Infiltration-based hydrologic model sensitivity to various storm characteristics will be tested.

Publications:

Bonta, J. V., Proposed use of Huff Curves for Hyetograph Characterization, ARS Weather and Climate Workshop, Denver, CO, 1995.

QUANTIFY RUNOFF GENERATION AND IDENTIFY DOMINANT HYDROLOGIC PROCESSES OVER A RANGE OF SCALES

Principle Scientist:	D.C. Goodrich
Cooperating Scientists:	L.J. Lane, D.A. Woolhiser, R.M. Shillito, C.L. Unkrich
ARS GCRP:	I.A.1.5
CRIS Numbers:	5342-13610-005-00D

Problem: While the non-linear nature of watershed runoff response for a given area has long been recognized, the literature suggests that watershed response may become more linear with increasing scale due to increased averaging at larger drainage areas and dominance of response by channel flow. However, these findings result primarily from more humid regions and this observation has not been tested in arid and semiarid regions. If linearity increases with increasing basin scale rules for model aggregation can be more easily.

Approach: To investigate the effect basin scale has on runoff production, observed runoff data for 31 nested watersheds within the Walnut Gulch Experimental Watershed (150 km^2) were analyzed. The spatial characteristics of over 300 storms were examined to assess the implications of partial area storm coverage. Modeling studies to estimate peak discharge rates for various return frequencies were conducted on all primary Walnut Gulch watersheds. A more detailed mechanistic model (KINEROS) was then applied on a specified subset of watersheds to further explore the nature of runoff response as a function of basin scale.

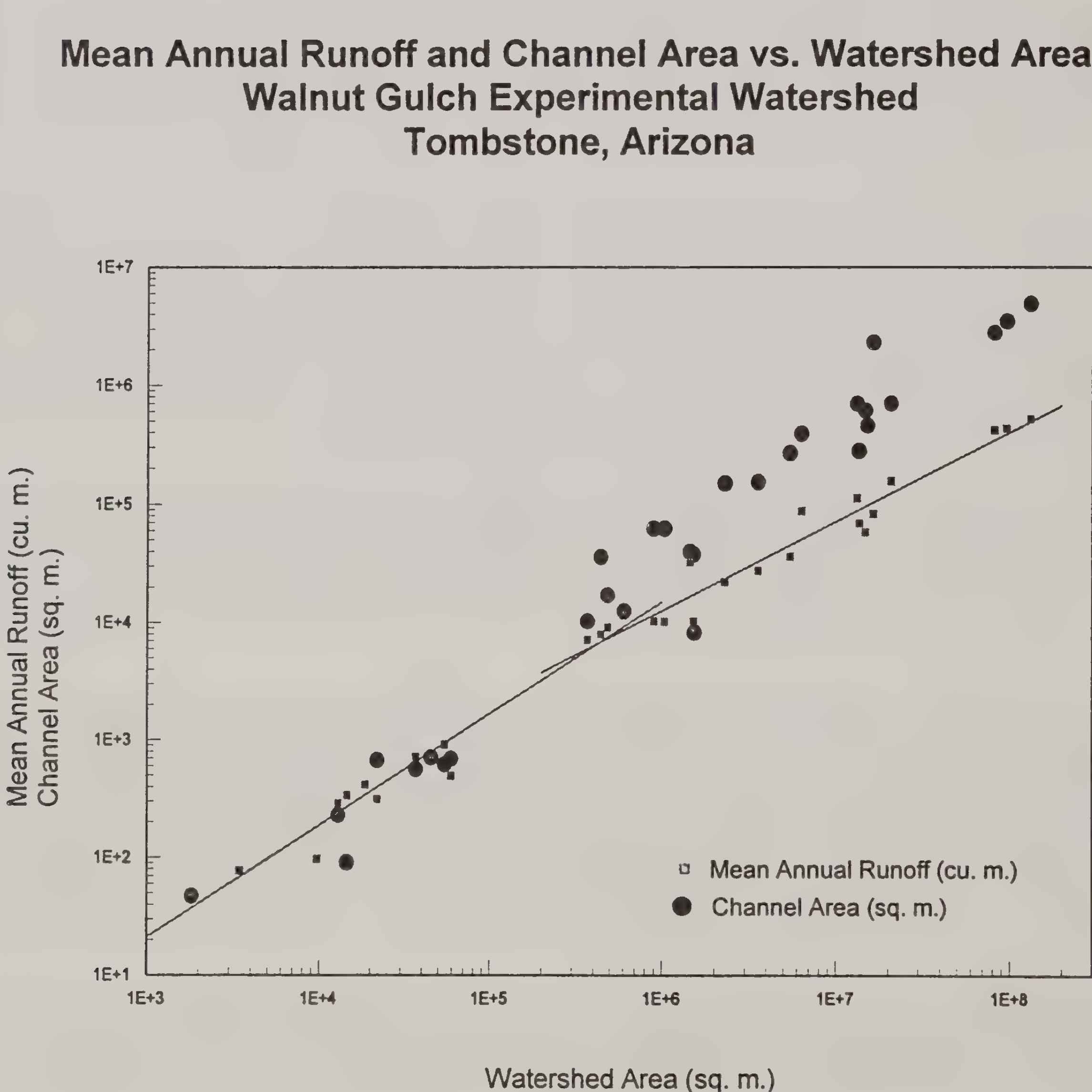
Findings: Analysis of the runoff data for the subwatersheds within Walnut Gulch indicated a transition in the rate of change of average runoff with increasing watershed size. An examination of channel area as a function of drainage area, especially the transition of drainage swales to incised channels, indicated the dominance of channel process vs. overland flow processes may also be a function of basin size.

Results of modeling 100-yr floods using the Walnut Gulch data indicated that spatial averaging of rainfall inputs to distributed models limit their performance in estimating flood frequency under the ephemeral nature of the Walnut Gulch watersheds. Additionally, runoff response in the ephemeral Walnut Gulch watersheds becomes more non-linear with both increasing watershed area and decreasing storm size. This is primarily due to the increasing effect of channel losses and associated infiltration-related threshold non-linearities, as well as to partial area storm coverage.

Future Plans: The results of this analysis are being prepared for an invited presentation to the next "Scale Issues in Hydrology" workshop to be held in June 1996. Manuscripts from this meeting will be submitted for publication in *Water Resources Research* on Nov. 1, 1996.

Notes:

A transition exists in the linear power law relationship between mean annual runoff and watershed area. At the transition region (~7E+5 sq. m.), a corresponding jump in the channel area versus watershed area relationship occurs. Subsequent modeling efforts indicate that this behavior is due to increasing channel losses as well as partial area storm coverage as basin scale increases. This results in runoff response which becomes more non-linear with increasing basin scale.



EVALUATING THE LOCAL IMPACTS OF OROGRAPHY ON METEOROLOGICAL VARIABLES

Principle Scientist:	D.C. Goodrich
Cooperating Scientists:	R.L. Scott, J.J. Toth
ARS GCRP:	I.A.1.5, I.A.4.1, V.B.1.1
CRIS Number:	5432-13610-005-00D

Problem: The lack of meteorological observations in mountain regions has severely hampered the investigation of orographic effects on rainfall and related meteorological parameters. The ability to extrapolate measurements made from more common "valley floor" locations into mountainous regions needs to examined.

Approach: The initial objective was to collect meteorological data at a variety of elevations throughout the San Pedro Basin in southeastern Arizona (the SALSA program study area), which includes the Walnut Gulch Experimental Watershed. Data sources included the Walnut Gulch Experimental Watershed, the Fort Huachuca Meteorological Team, and the National Weather Service.

Findings: Five years of daily precipitation data from stations at Fort Huachuca and National Weather Service stations in the San Pedro were examined. Preliminary orographic analysis of seasonal precipitation versus elevation were made to provide parameters to a Markov Chain model of daily precipitation occurrence. It was determined that model parameters varied significantly with elevation and season. Precipitation totals increased approximately 250 mm per (vertical) kilometer. Additionally, there was a higher correlation of elevation to precipitation in winter than in summer months. The orographic effect appeared to have a seasonal component, due to storm track. These results were presented at the International Union of Geodesy and Geophysics (IUGG) conference in Boulder, CO.

Rainfall, wind speed, relative humidity, atmospheric pressure, solar radiation, and soil temperature data gathered at 15-minute intervals from six automated stations was acquired. The data sites ranged from 1200 m to 2400 m in the Huachuca Mountains. After an initial assessment, the data quality was regarded as very good, although the bulk of the data since 1988 was stored in an electronic format inaccessible to current operating systems. Nevertheless, data from July 1990 to July 1992, and from February 1993 to April 1994 was recently made available and processed. Time series and spatial statistical analyses of the data to quantify orographic influences are underway.

Future plans: Validation fields for a parallel effort in meteorological modeling will be developed. Also, an analysis of the three separate ("Mexican") monsoons contained in the data will be carried out to identify patterns of wind, temperature and humidity that relate to strong and weak monsoon circulations.

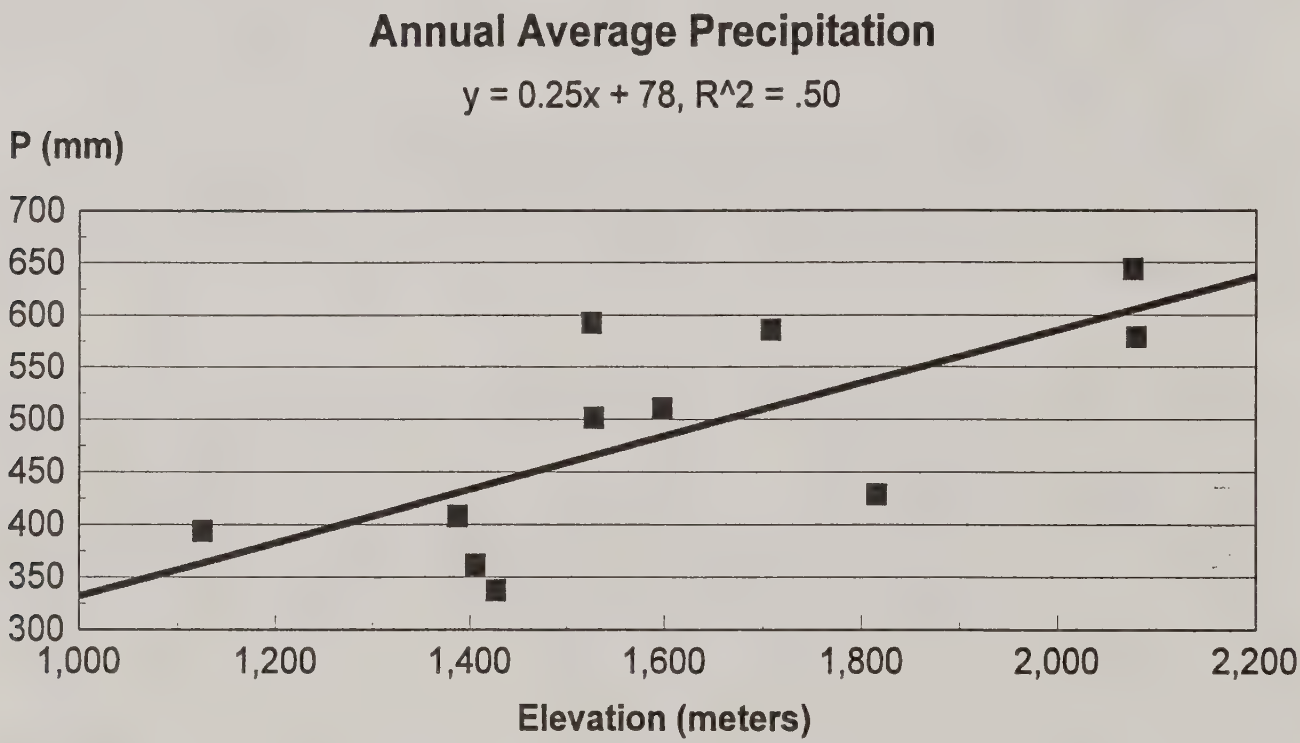
Publications:

Scott, R.L., and D.C. Goodrich, 1995. The influence of Topography on Precipitation Under the Distinct Summer and Winter Weather Patterns of Southeastern Arizona, *Abstracts of the XXI General Assembly of the International Union of Geodesy and Geophysics*, Boulder, CO, July 2-14, 1995. p. A210.

Notes:

Annual 1984-1994 averages for all stations in the Upper San Pedro Basin indicate a 250 millimeter increase in precipitation per kilometer in elevation increase.

Regressions separated by monsoon, winder, and dry seasons indicate a stronger orographic relationship (R^2 = .74) in winter. This is probably due to the north-south orientation of the mountains and a westward storm track.



Estimating the Impact of Increased CO_2 and Temperature on Soil Water Balance, Crop Yield and Soil Erosion Using WEPP-CO_2 Model

Principle Scientist: M. Reza Savabi

Cooperating Scientists: Jorg Ehrenreich, Claudio Stockle, Jeff Arnold, Jimmy Williams, Mark Nearing, Darrell Norton

ARS Global Change Research Program:

Research Areas:	I						III			IV
Program Elements:	A				C		A		C	A
Objectives:	1	2	3	4	1	2	1	2	1	1
Tasks:	4,5	1	1,3	2	8	9	2,3	1	2	1,2

CRIS Numbers: 3602-12000-003-00D and 3602-12000-006-00D

Problem: The global rise in the atmospheric concentration of carbon dioxide (CO_2) is well documented. However, the effect of increase of radioactive trace gasses and associated climatic changes on hydrology, crop yield and erosion need to be investigated on watersheds with various vegetation type, climate, management and soil conditions for future watershed planning and water resources management.

Approach: A modeling approach is being utilized to investigate the impact of increasing atmospheric CO_2 and temperature on water balance, plant growth, and soil erosion of watersheds in the U.S. and Austria. The evapotranspiration (ET) calculation of the USDA-Water Erosion Prediction Project (WEPP) computer model was modified and improved to reflect the effect of the atmospheric CO_2 changes on plant transpiration. Based on the current literature, the Penman-Monteith method was modified to simulate the impact of increasing CO_2 on stomata resistance to conduct water. Furthermore, the WEPP plant growth submodel was modified to simulates the effect of CO_2 fluctuation on radiation use efficiency and, therefore, conversion of photosynthetic active radiation to biomass. The new model, WEPP-CO_2 was evaluated using hydrometerological data from five watersheds in U.S. and two watersheds in Austria. The scenario used was that the average daily temperature and atmospheric CO_2 will increase linearly during next 50 years. The temperature will increase 3 C over the present temperature and CO_2 will increase by 160ppm over the present 330ppm by year 2046.

Findings: The results indicate that the water balance, crop yield, and soil erosion response to the increase of temperature and CO_2 depends on plant water use efficiency, type of soil and present climate situation. In general, and under the given scenario and sites tested, the increase of CO_2 coupled by temperature increase resulted in increased crop yield, leaf area index, ET and reduces storm runoff and soil erosion.

Future Plans: The effect of increased organic C due to enhanced plant growth by CO_2-enriched agro-ecosystem on soil water holding capacity, water intake, hydraulic conductivity, erodibility, and aggregate stability will be incorporated in WEPP-CO_2 model. The literature search will continue to make certain that the latest science in the global climate change area will be used in the WEPP-CO_2 model. Several other watersheds and basins with different climate, soil, and vegetation in the U.S. and abroad will be used in future work.

Publications

Savabi, M. R., J. G. Arnold, and A. D. Nicks, 1993. Impact of Global Climate Change on Hydrology and Soil Erosion: A Modeling Approach. In: Proceeding of the Industrial and Agricultural Impacts on the Hydrologic Environment, the second USA-CIS joint conference in Environmental Hydrology and Hydrogeology, Washington D.C., May, 1993. pp 3-18.

Savabi, M. R., D. Smith, P. P. Micklin, and O. Shamilievna. Possible Effect of Climate Change On Aral Sea-Level Fluctuation. Submitted for Publication in the Proceedings of the Symposium on Global Changes and Geography, to be held on August 14-18, 1995 in Moscow, Russia.

Savabi, M. R., D. C. Flanagan, B. Hebel and B. A. Engel. 1995. Application of WEPP and GIS to small watershed. Journal of Soil and Water Conservation, Vol. 50, No 5, pp. 477-483.

Savabi, M. R., D. C. Flanagan, B. A. Engel, M. A. Nearing, and B. Hebel. 1995. Application of WEPP and GIS to Predict Storm Runoff. In: Proceedings of The International Symposium on Water Quality Modeling, Kissimmee, Florida, April 2-5, 1995. PP: 348-357.

Savabi, M. R., A. Klik, and L. D. Norton. 1996. Assessing Soil Erosion Of Austrian Farmlands With WEPP Model. Accepted for publication in: the Proceedings of Sixth Federal Interagency Sedimentation Conference, to be held March 10-14, Las Vegas, NV. pp IX-98-106.

Savabi, M. R., A. Klik, , K. Grulich, J.K. Mitchell, and M. A. Nearing. 1996. Application of WEPP and GIS on Small Watersheds in the U.S. and Austria. Accepted for publication in the Proceeding of the "HydroGIS 96," an International Conference on Application of Geographic Information Systems in Hydrology and Water Resources Management. April 16-19, 1996 in Vienna, Austria. pp 469-476.

Savabi, M. R., W. A. Dugas, R. Wight., and J. Bonta. 1995. WEPP Water Balance Submodel: Model Description and Evaluation. Am. Soc. Ag. Eng, St. Joseph, MI. Paper No. 95-2387.

Favis-Mortlock, D. T. and M. R. Savabi. Shifts in Rates and Spatial Distributions of Soil Erosion and Deposition Under Climate Change, In: Anderson, M. G. and Brooks, S. (eds), Advances in Hillslope Processes, Wiley. Submitted Nov. 1995.

POSSIBLE IMPACT OF INCREASED CO_2 AND TEMPERATURE ON SOIL WATER BALANCE, CROP YIELD AND SOIL EROSION OF WATERSHEDS IN THE U.S. AND AUSTRIA.

Principle Scientist: Reza Savabi

Cooperating Scientists: Jorg Ehrenreich, Claudio Stockle, Mark Nearing and John Laflen.

ARS GCRP: Global climate change modeling

CRIS Numbers: 3602-12000-003-00D and 3602-12000-006-00D

Abstract

The global rise in the atmospheric concentration of carbon dioxide (CO_2) is well documented. However, the global and regional change in climate that may result from the rise in atmospheric concentration of CO_2 and other radioactive trace gasses remains the subject of intense debate. Yet, the effect of increase of radioactive trace gasses and associated climatic changes on hydrology, crop yield and erosion need to be investigated on watersheds with various vegetation type, climate, management and soil conditions for future watershed planning and water resources management. A modeling approach is being utilized to investigate the impact of increasing atmospheric CO_2 and temperature on water balance, plant growth, and soil erosion of watersheds in the U.S. and Austria. The evapotranspiration (ET) calculation of the USDA-Water Erosion Prediction Project (WEPP) computer model was modified and improved to reflect the effect of the atmospheric CO_2 changes on plant transpiration. Based on the current literature, the Penman-Monteith method was modified to simulate the impact of increasing CO_2 on stomata resistance to conduct water. Furthermore, the WEPP plant growth submodel was modified to account for the effect of a CO_2 increase on biomass production. The modified model simulates the effect of CO_2 fluctuation on radiation use efficiency and, therefore, conversion of photosynthetic active radiation to biomass.

The new model, WEPP-CO_2 was evaluated using hydrometerological data from Castana (IA), Holly Spring (MS), Morris (MN), and Presque Isle (ME) sites in US and Mistlebach and Pyhra watersheds in Austria. The scenario used was that the average daily temperature and atmospheric CO_2 will increase linearly during next 50 years. The temperature will increase 3 C over the present temperature and CO_2 will increase by 160ppm over the present 330ppm by year 2046. The results indicate that the water balance, crop yield, and soil erosion response to the increase of temperature and CO_2 depends on plant water use efficiency, type of soil and present climate situation. In general, and under the given scenario and sites tested, the increase of CO_2 coupled by temperature increase resulted in increased crop yield, leaf area index, ET and reduces storm runoff and soil erosion.

The literature search will continue to make certain that the latest science in the global climate change area will be used in the WEPP-CO_2 model. Several other watersheds in the U.S. and abroad will be used in future work. Watersheds which are being considered in the U.S. are Coshocton, OH; Riesel, TX; Reynolds Creek, ID; Walnut Gulch, AZ; and Coweeta Forest Station, NC.

Publications (Journals and Proceedings)

Savabi, M. R., J. G. Arnold, and A. D. Nicks, 1993. Impact of Global Climate Change on Hydrology and Soil Erosion: A Modeling Approach. In: Proceeding of the Industrial and Agricultural Impacts on the Hydrologic Environment, the second USA-CIS joint conference in Environmental Hydrology and Hydrogeology, Washington D.C., May, 1993. pp 3-18.

Savabi, M. R., D. Smith, P. P. Micklin, and O. Shamilievna. Possible Effect of Climate Change On Aral Sea-Level Fluctuation. Submitted for Publication in the Proceedings of the Symposium on Global Changes and Geography, to be held on August 14-18, 1995 in Moscow, Russia.

Savabi, M. R., D. C. Flanagan, B. Hebel and B. A. Engel. 1995. Application of WEPP and GIS to small watershed. Journal of Soil and Water Conservation, Vol. 50, No 5, pp. 477-483.

Savabi, M. R., D. C. Flanagan, B. A. Engel, M. A. Nearing, and B. Hebel. 1995. Application of WEPP and GIS to Predict Storm Runoff. In: Proceedings of The International Symposium on Water Quality Modeling, Kissimmee, Florida, April 2-5, 1995. PP: 348-357.

Savabi, M. R., A. Klik, and L. D. Norton. 1996. Assessing Soil Erosion Of Austrian Farmlands With WEPP Model. Accepted for publication in: the Proceedings of Sixth Federal Interagency Sedimentation Conference, to be held March 10-14, Las Vegas, NV. pp IX-98-106.

Savabi, M. R., A. Klik, , K. Grulich, J.K. Mitchell, and M. A. Nearing. 1996. Application of WEPP and GIS on Small Watersheds in the U.S. and Austria. Accepted for publication in the Proceeding of the "HydroGIS 96," an International Conference on Application of Geographic Information Systems in Hydrology and Water Resources Management. April 16-19, 1996 in Vienna, Austria. pp 469-476.

Savabi, M. R., W. A. Dugas, R. Wight., and J. Bonta. 1995. WEPP Water Balance Submodel: Model Description and Evaluation. Am. Soc. Ag. Eng, St. Joseph, MI. Paper No. 95-2387.

Favis-Mortlock, D. T. and M. R. Savabi. Shifts in Rates and Spatial Distributions of Soil Erosion and Deposition Under Climate Change, In: Anderson, M. G. and Brooks, S. (eds), Advances in Hillslope Processes, Wiley. Submitted Nov. 1995.

Use of Remotely Sensed Data to Quantify Rangeland Vegetation and Plant Community/Atmosphere Interactions

Principle Scientists:	Albert Rango, Kris Havstad
Cooperating Scientists:	Jerry Ritchie, William P. Kustas, Tom Schmugge, John Prueger, Jim Everett, Frank Schiebe, Karen Humes, Larry Hipps
ARS GCRP:	Res. Areas: I; Prog. Elements: A; Objs.: 1; Tasks: 5
	Res. Areas: I; Prog. Elements: A; Objs.: 2; Tasks: 2
	Res. Areas: I; Prog. Elements: A; Objs.: 3; Tasks: 4.
CRIS Numbers:	1270-13660-005-00D

Problem: There is a significant need to quantify and better understand the interaction of vegetation communities with the lower atmosphere, including feedback mechanisms arising from plant responses to changes in atmospheric and hydrologic fluxes. It is particularly important to obtain this information in a spatially distributed manner in order to quantify these relationships at various spatial scales.

Approach: Conduct a multilevel, multisensor field program at the Jornada Experimental Range in southern New Mexico during dry and wet seasons over a number of years to assess areal vegetation patterns and energy and water fluxes. Combine detailed ground measurements with aircraft remote sensing and satellite imagery in an attempt to scale up to large regions. Use historical data and current measurements to evaluate the response of rangeland vegetation communities to both short and long term changes in climate and management practices.

Findings: Intensive three day study periods for ground and airborne campaigns have been conducted in May 1995 and May 1996 (dry season), February 1996 (dormant season), and September 1995 (wet season). Thermal, multispectral, 3-band digital video, and laser altimetry profile and scanning laser data have been collected from aircraft platforms. Bowen ratio-energy balance stations were established for long term measurements in the grass and shrub dominated communities. Periodic supplemental measurements have been made using eddy correlation techniques. Ground based measurements during the field campaigns include thermal and multispectral measurements. Measurements of vegetation species and height were made in support of the laser altimeter data and supplemented with leaf area index measurements. Ground and aircraft measurements were scheduled to coincide with Landsat-TM overpasses.

Preliminary results indicate that multilevel, multisensor remote sensing shows rangeland vegetation differences areally and temporally. Linkage to satellite multispectral satellite data should provide more powerful information over larger areas. Remote sensing information at various levels provides a way to scale up from detailed ground studies in the Jornada.

Future Plans: Data collection will continue for the September 1996 wet season campaign. Data analysis will continue and be directed by the results of a meeting of scientists involved in JORNEX on July 24-25, 1996. We hope to continue the measurements in Jornada for 1997-98 and extend the work along vegetation and precipitation gradients to include the Sevilleta National Wildlife Refuge, NM and the Central Plains Experimental Range, CO to the north.

Publications:

Ritchie, J. C., Rango, A., Kustas, W. P., Schmugge, T. J., Brubaker, K., Zhan, X., Havstad, K. M., Nolan, B., Prueger, J. H., Everett, J. H., Davis, M. R., Schiebe, F. R., Ross, J. D., Humes, K. S., Hipps, L. E., Ramatingam, K., Menenti, M., Bastiaanssen, W. G. M., and Pelgrum, H., 1996. JORNEX: An airborne campaign to quantify rangeland vegetation change and plant community-atmospheric interactions, Proceedings of the Second International Airborne Remote Sensing Conference and Exposition, San Francisco, 13 pp.

Rango, A., Ritchie, J. C., Kustas, W. P., Schmugge, T. J., Brubaker, K. L., Havstad, K. M., Prueger, J. H., and Humes, K. S., 1996. JORNEX: A remote sensing campaign to quantify rangeland vegetation change and plant community/atmospheric interactions, Proceedings of the Second International Scientific Conference on the Global Energy and Water Cycle, Washington, D. C., 2 pp.

Title: INSTALLATION OF THE ROOT ZONE WATER QUALITY MODEL INTO THE MODULAR MODELING SYSTEM (MMS)

Principle Scientests: C. Bierbaum, K. Rojas, and L.R. Ahuja

Cooperating Scientists:

ARS GCRP: Res. Areas: 1 ; Prog. Element: A ; Objs: 1 ; Tasks: 5,6.

CRIS Numbers: 5402-13610-003-00D

Problem: MMS is a software developed by the USGS for the purpose of providing a common framework for the development and testing of process based modules and to facilitate integration of these process modules into operational physical models. By providing a consistent framework for model development and application, it is hoped that the installation of the Root Zone Model in MMS will enhance the integration of related ARS process modules into the model. In addition, the graphical interfaces supported in MMS assist users in parametetrization of model components and the visualization of model output. It is hoped that this installation will demonstrate the efficiency of implementing research models within a common framework and provide a tool to focus multidisciplinary research efforts.

Approach: Define distinct process modules within in the Root Zone Model which serve as the basic building blocks for the overall combined model structure in MMS. When these modules do not satisfy the required MMS coding structure, rewrite the module source code while maintaining the same functionality and capabilities as the unmodified version of RZWQM. Within each of the identified process modules, define a consistent naming convention for that module's input parametetrization variables and output display variables. This convention should produce a concise name which is consistent with current scientific nomenclature and provides the user with a clear understanding of the variables context within the associated process module.

Findings: Version 3.0 of the Root Zone Water Quality Model has been implemented into the MMS software. This implementation is an initial test version which will require some additional restructuring of the modules and further instructional documentation to achieve the expressed goals as outlined above. However, this initial work has demonstrated that efficient incorporation of process modules can be enhanced within the MMS system; as two process modules from the USGS-Precipitation Runoff Modeling System have been integrated as modules into the Root Zone Model.

Future Plans: Further segregation of the current modules will help promote interaction with RZWQM at a more basic algorithmic level. With this additional segregation, it is felt that the MMS platform will be a valuable tool for efficient installation of new process modules into RZWQM, and that this platform will also assist the Agricultural Research Service in examining the potential of MMS as a common software for all ARS models. In addition, a more clearly defined variable naming structure and additional on-line module documentation, will provide users with a more complete understanding of variable/process association and model capabilities. Finally, a more powerful graphical post-processing software will further assist users in the visualization and assessment of modeling results.

Title: REMOTE SENSING AND INTEGRATION OF SOIL WATER AND ENERGY TRANSFER PROCESSES OVER LARGE AREAS

Principle Scientists: L.R. Ahuja, K.E. Johnsen, T. Engman, and N. Matakali

Cooperating Scientists:

ARS GCRP: Res. Areas: 1 ; Prog. Elements: A ; Objs: 1 ; Tasks: 5,6.

CRIS Numbers: 5402-13610-003-00D

Problem: The simultaneous description of moisture and heat energy exchange at the soil surface is an important aspect of the total mass and energy balance in a watershed. Knowledge of the physics of the system, field measurements of the processes of exchange, together with the factors involved with scaling from point to large basins, is required for proper simulation.

Approach: This project has two objectives: (1) Investigate the potential of obtaining subsurface soil hydraulic properties from remote-sensed surface soil moisture changes and available soil map information using the Root Zone Water Quality Model (RZWQM); (2) Evaluate the convergence scaling theory for integrating water and energy fluxes over large areas.

For Objective 1, the remote-sensed and gravimetrically measured surface moisture data from several parts of the Little Wachita watershed in 1992 will be utilized. First estimates of subsurface soil hydraulic parameters will be obtained from available soil survey data on texture and bulk density using the SOILPROP subroutine of RZWQM. These estimates will then be refined by calibrating the RZWQM-simulated values of surface moisture changes against the measured values. The final calibrated estimates will be validated against field measurements for selected cases. For Objective 2, the RZWQM model will be linked to GIS technology and the databases (soils, topography, climate, channels) for the Little Wachita Watershed. Starting with uniform initial conditions and assuming uniform weather conditions, the model will be run for each pixel to generate data on water and heat fluxes. The scaling of these fluxes with respect to scaling of soil hydraulic parameters will then be explored.

Findings: The soil hydraulic properties of water retention and hydraulic conductivity as functions of soil water content or potential for several different horizons have been obtained from surface water content measurements for 15 sites of the Little Wachita watershed. The calibration fits looked good in all cases.

Future Plans: The above calibration method will be validated against theoretical surface water content data generated by numerical solutions for three different soil types. In addition, the method will be tested in the field at five (out of 15) selected locations by measuring hydraulic properties of the subsurface horizons and soil surface water content changes after a thorough wetting. Later, the work outlined above for objective 2 will be undertaken.

Publications:

Ahuja, L.R., K.E. Johnsen, and G.C. Heathman. 1995. Macropore transport of a surface-applied chemical: model evaluation and refinement. Soil Sci. Soc. Am. J. 59:1234-1241.

Johnsen, K.E., H.H. Liu, J.H. Dane, L.R. Ahuja, and S.R. Workman. 1995. Simulating ..... Root Zone Water Quality Model ..new model, WAFLOWM. Trans of the ASAE. 38(1); 75-83.

Mattakali, N.M., E.T. Engman, L.R. Ahuja, and T.J. Jackson. 1995. Estimating soil properties from remote sensing of soil moisture. Proc. "SPIE"Conf., France, Sept. 25-29.

Mattakali, N.M., E.T. Engman, L.R. Ahuja, K.E. Johnsen, and T.J. Jackson. 1995. Effects of scale and spatial variability ..... conductivity using remote sensing and GIS. Workshop on Scaling in Hydrology, England.

Title: SIMULATING YEAR-ROUND ENERGY AND WATER FLUX UNDER CROP RESIDUES

Principle Scientists: R.M. Aiken, G.N. Flerchinger, K.L. Johnsen, H.J. Farahani, L.R. Ahuja, D.C. Nielsen, and K.W. Rojas

Cooperating Scientists:

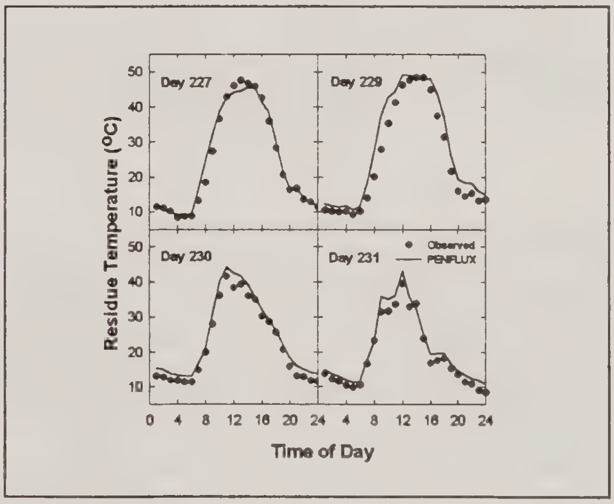
ARS GCRP: Res. Areas: 1 ; Prog. Element: A ; Objs: 1 ; Tasks: 5,6.

CRIS Numbers: 5401-13510-003-00D

Problem: Residue architecture (standing height, percentage soil cover, reflectance, etc.) modifies soil warming and water conservation by shading and 'insulating' surface soil layers. Decay of residue, dependant upon temperature and water conditions, results in seasonal changes in residue architecture, with impacts on soil temperature and water status. Winter freeze-thaw conditions complicate analysis of residue effects on soil and water management. Accurate simulation of year-round energy and water exchange processes provide analytic tools guiding residue management.

Approach: Crop residue impacts on energy and water exchange are quantified by PENFLUX, a soil-residue energy balance module providing boundary conditions for soil heat and potential evaporation modules of the Root Zone Water Quality Model (RZWQM). Year-round simulation of residue impacts by RZWQM is provided by incorporating energy exchange modules of SHAW, a process-level simulation model including freeze-thaw thermal dynamics of soil. Predictive accuracy of energy balance simulation is determined by comparing simulation results with micrometeorological observations acquired under dryland wheat, corn, sunflower and millet residues.

Findings: We refined near-surface exchange coefficients in the PENFLUX module, enhancing predictive accuracy, depicted in the adjacent figure. A manuscript describing the PENFLUX module is submitted for publication, subject to peer-review. We also completed merger of SHAW energy exchange processes into a beta test version of RZWQM, verifying simulation consistency with previous RZWQM results for a MSEA water quality demonstration site.



Future Plans: The PENFLUX module requires a companion residue water balance, under development, for accurate simulation of thermal conditions following precipitation or dew accumulation events. Further evaluation of SHAW and PENFLUX modules will utilize archived data acquired at Pullman, WA, Fort Collins, CO, and Akron, CO representing a range of residue architectures in semi-arid climates. Manuscripts reporting the predictive accuracy of these modules under winter and non-freezing conditions are in preparation.

Publications:

McMaster, G.S., R.H. Erskine, D.B. Palic, R.M. Aiken, and G.H. Dunn. 1995. Tillage and residue. I. Effects on surface soil temperature in dryland wheat-fallow system. Agronomy Abstracts, p. 20.

McMaster, G.S., D.B. Palic, R.H. Erskine, G.H. Dunn, and R.M. Aiken. 1995. Tillage and residue. II. Effects on soil water in dryland wheat-fallow system. Agronomy Abstracts, p. 20.

RASTER AGGREGATION OF DIGITAL ELEVATION MODELS AND ACCURACY OF EXTRACTED LANDSCAPE PARAMETERS

Principle Scientist: Jurgen Garbrecht
Cooperating Scientist: Lawrence Martz
ARS GCRP: Res. Areas: I; Prog. Elements: A; Obj.: 1; Task: 5, and Task: 7.
CRIS Number: 6220-13610-008-00D

Problem: The increasing availability of Digital Elevation Models (DEM) allows the automated and rapid determination of landscape parameters. However, the effect of DEM grid size on the accuracy of the extracted parameters is not well established. A systematic analysis on the effect of grid size is necessary to develop DEM resolution guidelines for proper extraction of landscape drainage features.

Approach: Assemble a set of DEMs representing landscapes from different geographic locations. Use the finest available resolution to establish baseline parameter values for the representation of the network and subcatchments. Then, stepwise aggregate the DEM grid size and visualize the discrepancies of the extracted parameter values from the baseline as a function of grid size.

Findings: The reported findings are preliminary because research is ongoing. DEMs of 12 watersheds ranging in size from 7.0 to 617 km^2 and with base resolution ranging from 5 to 30 meters were evaluated for as many as 14 extracted network and subcatchment parameters. The discrepancies between baseline and aggregated values were plotted against a dimensionless grid size parameter. In general global parameters such as total watershed area, total channel length, and drainage density proved to be more stable during aggregation than parameters that are in some way related to the number of channel links, such as number of channels, total source area and mean drainage area per channel link. Also, channel elevation values appeared to be quite stable with a slight, but systematic, increase for larger grid sizes.

Future Plans: Pending development and approval of El Reno research program: Current research will be continued. Additional DEMs will be included into the analysis as they become available. Additional parameters will be included as necessary. Research will also address the issue of vertical DEM resolution. The impact of the aggregation and loss of information on hydrologic processes will be established and a set of guidelines for proper DEM resolution will be formulated.

Publications: (since Norman, Oklahoma, 1994 meeting)

Garbrecht, J., and L. W. Martz. 1994. Grid Size Dependency of Parameters Extracted from Digital Elevation Models. Computers and Geosciences, 20(1):85-87, 1994.

Garbrecht, J. and P. J. Starks. 1995. Notes on the Use of USGS Level 1 7.5-Minute DEM Coverages for Landscape Drainage Analysis. Photogrammetric Engineering and Remote Sensing, 61(5):519-522, May 1995.

Garbrecht, J., and L. W. Martz. 1995. Comment on "Digital Elevation Model Grid Size, Landscape Representation, and Hydrologic Simulation" by Weihua Zhang and David R. Montgomery. Water Resources Research. Accepted for Publication.

IMPACTS OF DEM DATA FORM, TYPE & RESOLUTION ON HYDROLOGIC MODELING

Principle Scientists:	D.C. Goodrich, J. Garbrecht, T. O. Keefer
Cooperating Scientists:	O. Palacios, R. Grayson, G. Blöschl, G. Willgoose (All non-ARS)
ARS GCRP:	I.A.1.7, 1.A.2.1
CRIS Numbers:	5342-13610-005-00D

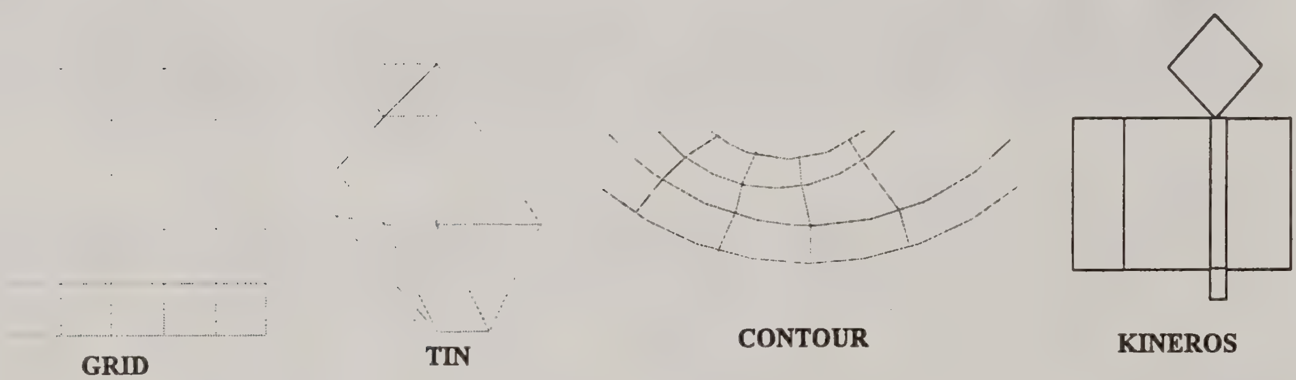
Problem: A crucial link between many resource models and a GIS is spatially distributed digital elevation model (DEM) data. The three primary forms of DEM data are grid, contour and triangular irregular network (TIN) data. Each type has advantages and disadvantages for data storage and surface representation. However, a comparative evaluation of the relative advantages and disadvantages of each DEM data type for hydrologic modeling has not been conducted. In addition the assessment of type and resolutions of DEM data on a given hydrologic model have not be evaluated in a location with independently derived DEM data.

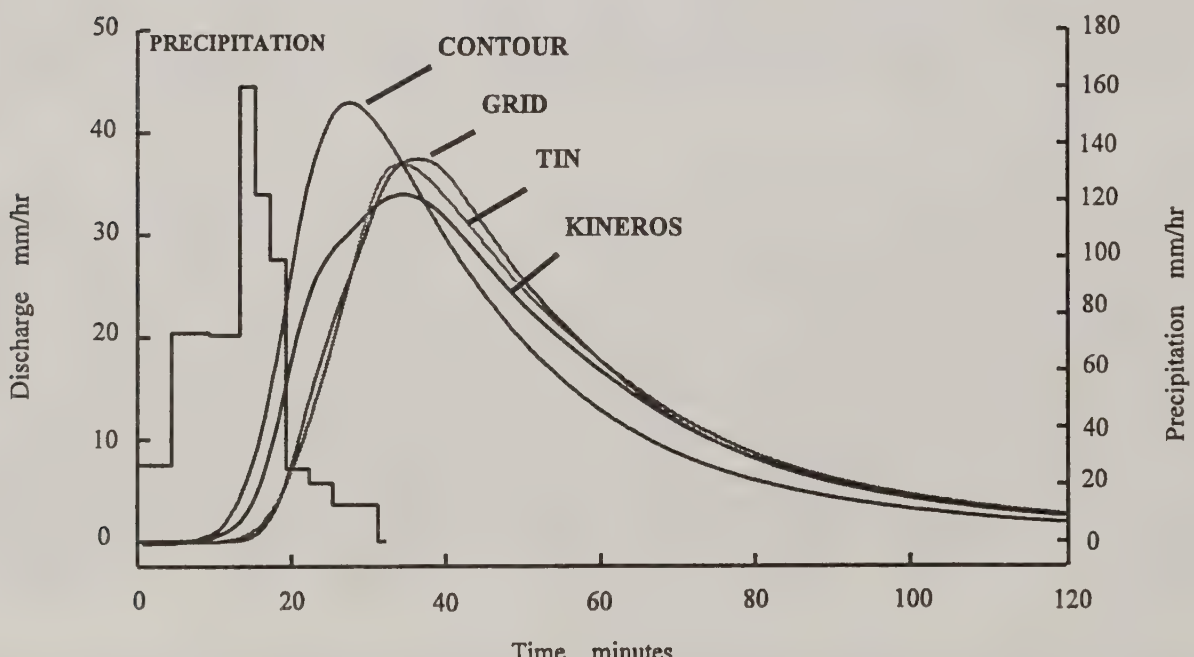
Approach: Five modeling groups have collaborated on this project with models based on TIN, contour and grid DEM data as well as on a kinematic cascade and a hybrid case. Routing cases where then developed for a simple overland flow plane, an open book geometry (2 planes to a channel) and for the simple first order R5 watershed. The first two cases were carefully contrived to establish the variation in routing among to models that is attributed to numerical implementation. Collaboration with J.Garbrecht is also occurring to modify the TOPAZ topographic analysis software to derive basin attributes and KINEROS geometric model parameter from DEM data. This will be used on 4 independently derived DEM data sets (USGS, SPOT, Radar, Laser Altimeter) over Walnut Gulch to quantify the impacts of DEM type and resolution on rainfall-runoff modeling.

Findings: The results have been collated with 4 of the 5 models showing virtually identical results to the analytic solution on the single overland plane case and to the characteristic solution for 4 of the 5 models for the open book case. This demonstrates that the numerical implementation of these models is good and that the errors or variation in routed runoff results due to numerical errors are small. For the third case of the R5 watershed geometry it is impossible to maintain the same geometric representation and computational node. With this case the impacts of topographic representation on routing will manifest themselves. When the models were applied to the R5 geometry for a natural rainfall events the computed peak runoff rate ranged from 34 to 48 mm/hr. This demonstrates that the form of topographic representation can have large impacts on routing that are far larger than differences resulting from numerical implementation. The assessment of DEM type and resolution on modeled runoff has only recently been initiated.

Future plans: Attempt to explain the differences in routing impacts by computing the distribution of flow lengths and kinematic equilibrium storage for the R5 watershed. Prepare a manuscript summarizing the group's work for submission to *Water Resources Research* (tentatively entitled "Topographic Representation Impacts on Surface Routing"). For the assessment of DEM type and resolution on modeled runoff field surveys will be completed to verify the accuracy of the DEM data. In addition the TOPAZ algorithm will be applied to the various data sets to compare the impacts on derived basin attributes. Runoff model geometries from the various DEM data sets will then be derived over several subwatersheds in Walnut Gulch to assess there impacts on model outputs over a range of observed rainfall-runoff events.

Notes:
Digital Elevation Model (DEM) data may be used to automatically extract watershed geometry inputs for surface runoff hydrologic models. There are three principal DEM representations, Grid-based networks, Triangular Irregular Networks (TIN) and Contour-based networks and each will produce a unique model watershed surface. The variability of model hydrograph results for non-uniform precipitation input clearly indicates the effect of DEM watershed description, as all other input variables (e.g. roughness and calculation timestep) and model components (e.g. number of calculation nodes) are equivalent.





AUTOMATED LANDSCAPE CHARACTERIZATION FROM DIGITAL ELEVATION MODELS

Principle Scientist: Jurgen Garbrecht
Cooperating Scientist: Lawrence Martz
ARS GCRP: Res. Areas: I; Prog. Elements: A; Obj.: 1; Task: 7, and Obj.: 2; Task: 1, and Obj.: 3; Task: 1.
CRIS Number: 6220-13610-008-00D

Problem: Topography plays an important role in the description, quantification and interpretation of many hydrologic processes. Existing software that process Digital Elevation Models (DEM) have limitations and do not address specific hydrologic aspects that are needed in global change research.

Approach: Modify existing DEM processing technology to overcome limitations, introduce new procedures that address specific hydrologic needs (runoff, energy flux, erosion, remote sensing), and produce a comprehensive DEM processing software-tool (only algorithms for DEM processing, no GUI).

Findings: The following three components were developed and implemented as software components into the digital landscape analysis tool TOPAZ (see below): an improved treatment of spurious depression in DEMs; a new approach for drainage identification in flat areas; and, an automated recognition of drainage network and subcatchment topology from a raster image of the network. A comprehensive digital landscape analysis tool, called TOPAZ, was produced for topographic evaluation, drainage identification, watershed segmentation, and subcatchment parameterization. The software has a wide range of application potential in hydrology and is used by ARS, NRCS, NASA, Universities and industry.

Future Plans: Pending development and approval of El Reno research program: Implement TOPAZ in FORTRAN 90 to take advantage of the dynamic memory allocation and the interface to C software. Introduce a component to compute the parameters of the Wooding open-book subcatchment approximation for modeling of surface runoff and erosion. Allow the for user specified drainage network nodes. Implement new and faster raster processing techniques for effective use on large DEM coverages.

Publications: (since Norman, Oklahoma, 1994 meeting)

Garbrecht, J., L. W. Martz, and P. J. Starks. 1994. Automated Watershed Parameterization from Digital Landscapes: Capabilities and Limitations. In: Proceedings of 14th Annual American Geophysical Union Front Range Branch Hydrology Days, Colorado State University, Fort Collins, Colorado, pp. 123-134, April 1994.

Garbrecht, J. and L. W. Martz. 1995. TOPAZ: An Automated Digital Landscape Analysis Tool for Topographic Evaluation, Drainage Identification, Watershed Segmentation and Subcatchment Parameterization; TOPAZ Overview. U.S. Department of Agriculture, Agricultural Research Service, Durant, Oklahoma, USA, ARS Publication No. NAWQL 95-1, 16 pp., August 1995.

Garbrecht, J. and L. W. Martz. 1995. Advances in Automated Landscape Analysis. In: Proceeding of the First International Conference on Water Resources Engineering, Eds. W. H. Espey and P. G. Combs, American Society of Civil Engineers, San Antonio, Texas, Vol. 1, pp. 844-848, August 1995.

Garbrecht J., and L. W. Martz. 1996. Digital Landscape Parameterization for Hydrologic Applications. In: Proceedings of HydroGIS '96, International Conference on Application of Geographic Information Systems in Hydrology and Water Resources Management, Vienna, Austria, April 1996.

Garbrecht J., and L. W. Martz. 1996. Subcatchment Parameterization for Surface Runoff Modeling using Digital Elevation Models. In: Proceedings of the American Society of Civil Engineers Hydraulics Conference, North American Water and Environment Congress '96, Anaheim, California, June 1996.

Garbrecht J., P. J. Starks, and L. W. Martz. 1996. New Digital Landscape Parameterization Methodologies. In: Proceedings of the 32nd Annual Conference and Symposium "GIS and Water Resources" of the American Water Resources Association, September 22-26, 1996, Fort Lauderdale, Florida. Accepted for publication.

Garbrecht, J. and L. W. Martz. 1995. Drainage Identification Over Flat Surfaces in Raster Digital Elevation Models: a Hydraulic-Geomorphic Approach. Journal of Hydrology. Accepted for publication.

REGIONAL-SCALE SURFACE FLUX ESTIMATION USING REMOTE SENSING AND METEOROLOGICAL DATA

Principle Scientists: M.S. Moran, A.F. Rahman
Cooperating Scientists: J.C. Washburne, S. Sorooshian
ARS GCRP: I.A.1.7, I.A.2.2
CRIS Numbers: 5344-13660-001-00D, 5432-13610-005-00D

Problem: Remotely-sensed spectral data can be combined with conventional meteorological data for regional scale energy balance estimates. To combine point-based meteorological measurements with spatially-continuous remotely-sensed data, correct methods need to be developed for interpolating point-source meteorological data over a heterogeneous region. On the other hand, remotely-sensed data is temporally instantaneous and generally obtained only at one time of day. Thus, methods are also needed to convert remotely-sensed estimates of instantaneous evaporation rates to daily totals of surface fluxes of any region.

Approach: Using a physically-based approach, conventional meteorological measurements were combined with a digital elevation map (DEM) of the study area to produce spatially-continuous maps of air temperature, vapor pressure, and wind speed. Maps of surface resistance to energy flux transfer were produced based on published estimates of resistances for a variety of vegetation types combined with a regional vegetation map. With these data layers and remotely-sensed images of surface temperature and reflectance, maps of instantaneous evaporation rates were produced.

Findings: Regional maps of ambient temperature based on several meteorological stations combined with DEM data were found to be accurate. Extrapolation of wind speed and vapor pressure were more difficult, and with the present approach, the error was significant. Regional estimates of aerodynamic resistance to sensible heat transfer based on the vegetation biome map appeared to be accurate based on comparison with ground information. The combination of these data layers with remotely-sensed spectral images resulted in a good estimation of surface fluxes. This approach did allow reasonable estimates of surface fluxes in areas where meteorological data were not locally available.

We found that instantaneous estimates of surface flux could be safely extrapolated to estimate daily flux values if the relation between the instantaneous and daily values of the remotely sensed estimates of surface radiation were established. These relationships are found to be dependent on the surface conditions..

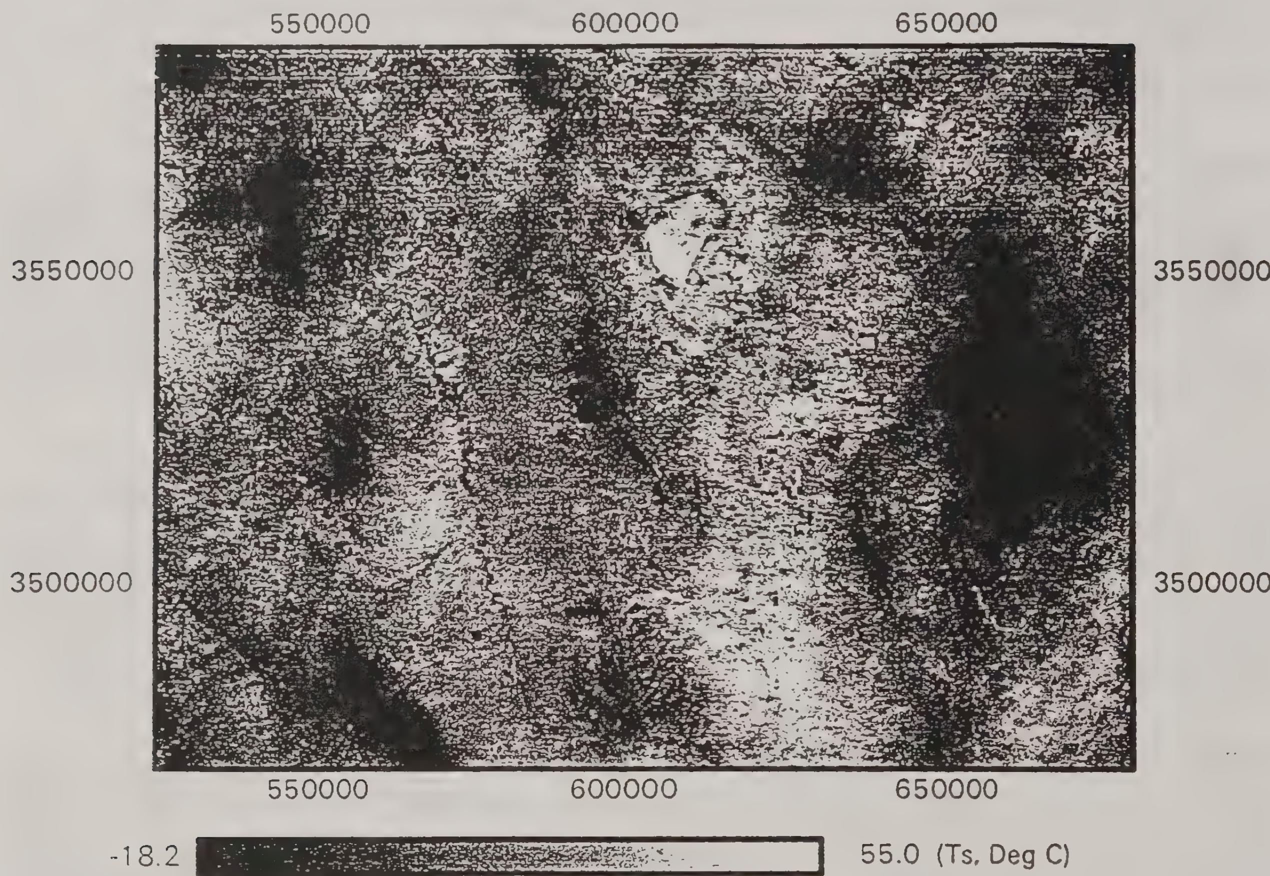
Future Plans: The techniques for extrapolating vapor pressure and wind speed will be investigated to get a more accurate result. Also, the validation techniques and sensitivity of different parameters of the energy balance models will be studied.

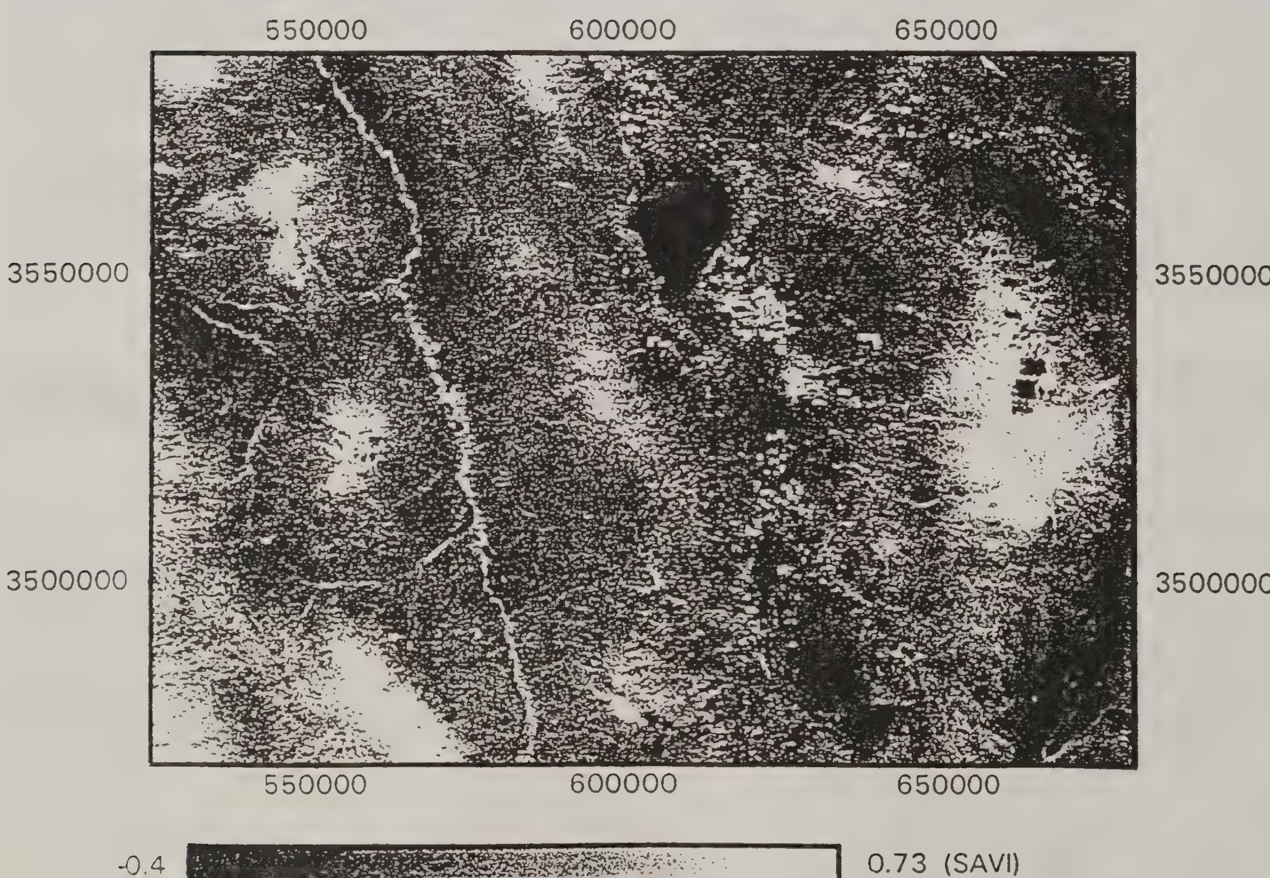
Publications:

Rahman, A.F., J.C. Washburne, M.S. Moran, A.K. Batchily, 1996. Regional-Scale Surface Flux Estimation by Combined Use of Remote Sensing and Meteorological Data. *Rem. Sens. Env.* (submitted May 1996).

Rahman. A.F. and M.S. Moran, 1996. On the Use of Mid-Morning Remotely Sensed and Ground-Based Data to Estimate Daily Evapotranspiration. *J. Agric. For. Met.* (submitted June 1996).

Notes:
Images of the surface temperature and SAVI of the study region on 10 June 1992.





INCORPORATION OF NEW TECHNOLOGIES INTO A NEW GENERATION OF HYDROLOGIC MODELS

Principle Scientists: J.J. Stone, D.C. Goodrich
Cooperating Scientists: S.N. Miller
ARS GCRP: I.A.2.1
CRIS Numbers: 5432-13610-005-00D; 5342-12660-001-00D

Problem: Technical issues and time constraints have limited geomorphologic investigations of Southwest rangelands. Traditional field-based measurements of basin features are unworkable for large areas due to the large number of measurements and quantity of spatial data that must be accounted for. However, the accurate geomorphologic analysis of watershed parameters is crucial to the proper modeling and understanding of hydrologic processes.

Approach: A geographic information system (GIS) was used to analyze subwatersheds within Walnut Gulch Experimental Watershed, near Tombstone, Arizona. Simultaneously, measurements of channel morphology and field verification of the GIS findings were taken in the field. Channel shape characteristics from field research were related to basin parameters extracted from the GIS. Important basin and channel characteristics for input into hydrologic simulation models were extracted from the GIS.

Findings: Channel morphology (cross-sectional area, width, and depth) was found to be strongly related to watershed characteristics such as basin shape, size, and the maximum length of flow within the watershed. The strong deterministic relationships between channel and basin variables, allows data extracted from a high-resolution GIS, such as exists for Walnut Gulch, to be used to derive channel characteristics. Hydrologic routing functions may be improved with the integration of GIS since channel variables can be derived and stored in a spatial database for parameterization of the model. Both distributed and conceptual models require the area under investigation to be divided into hydrologic response units, each of which must be characterized and defined by the spatial data within its borders. Rules used in the subdivision of watersheds may be re-created in a GIS so that basins may be characterized at a large scale with a minimum of user input. Sub-basins may be quickly and accurately defined and captured in a series of parameter files created by the GIS. This has strong implications for the development of a basin-scale hydrologic model, currently under development in coordination with the GIS.

Future Plans: Automation of the articulation of sub-basins and the generation of parameter files for many distributed and conceptual models is of primary importance so as to improve the functionality of the GIS-model interface.

Publications:
Miller, S. N., 1995. *An analysis of channel morphology at Walnut Gulch: linking field research with GIS applications.* Master's Thesis. 167 pp.

Masterson, J., S.N. Miller, and D. Yakowitz, 1996. Software enhancements to the USDA multi-objective decision support tool. *Proceedings of Malama 'Aina: Multiple Objective Decision Making for Land, Water, and Environmental Management, Honolulu, HI, July 23-28, 1995.* In press.

Notes:

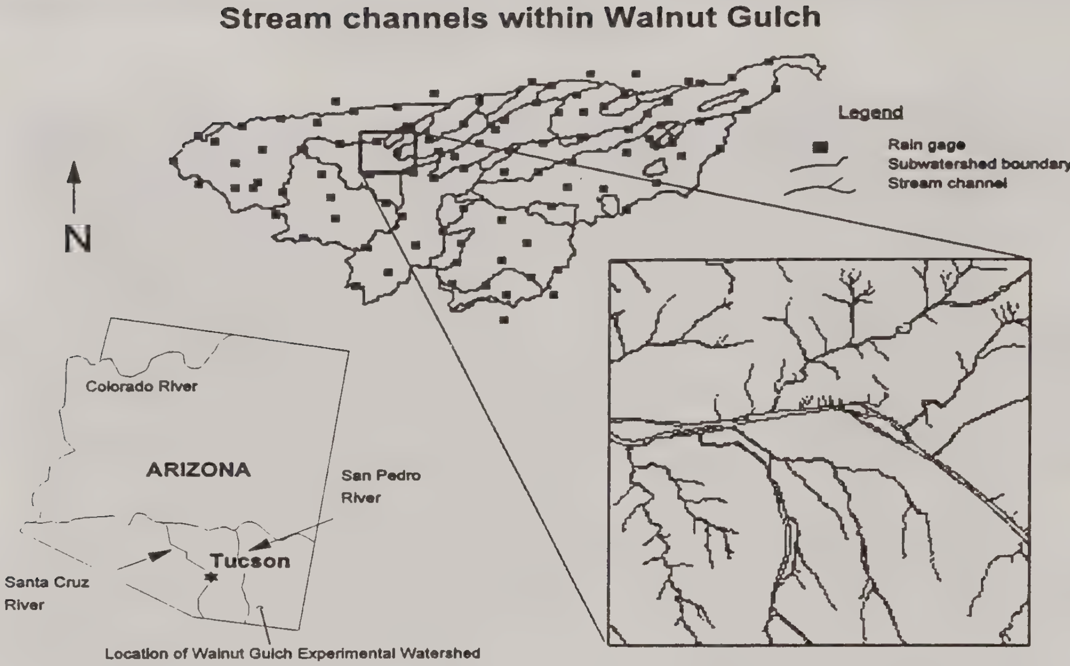


Figure 1: Digitized stream channels.

Variable	Watershed characteristic	r^2	coefficient	constant	Se_{yx}
log channel area	log watershed area	0.68	0.49	-2.44	0.34
channel area	maximum flowlength	0.79	0.001	1.83	3.46
channel area	area:perimeter ratio	0.77	0.03	0.17	3.60
log channel area	log cumulative channel length	0.62	0.51	-1.38	0.40

Table 1: Results of linear regression analysis between channel area and watershed variables

Because it takes into account both the width and depth of a channel, cross-sectional area is a good indicator of erosive energy and peak runoff volume. A comparison between cross-section survey data and watershed characteristics revealed that cross-sectional area is strongly related to several watershed variables. This implies that watershed characteristics may be used to determine channel variables for input into hydrologic simulation models.

Use of Remote Sensing to Measure Soil Water and Vegetation in semiarid Rangelands

Principle Scientists: Mark Seyfried, Jerry Ritchie, Peggy O'Neill
Cooperating Scientists: Gerald Anderson, Christopher Neale, Sudhir Goyal, Ted Engman.
ARS GCRP: Program Element I, Objective 2, Task 2
CRIS Numbers: 5362-12610-001 and 5362-13610-004

Problem: Existing models of hydrological processes are rigorous only at very small scales. It is important that our scientific knowledge be extended to more socially and economically relevant scales. For example, the questions posed by the potential for global climatic change require that very large scale (global) climatic changes be translated into small scale hydrologic effects and, for verification purposes, small scale measurements need to be translated into large scale parameters. The spatial variability of the landscape prohibits the use of current hydrological models. Remote sensing offers the potential for providing spatially varying input to these models. At this point, however, it is not known how to integrate remote sensing and modeling because remote sensing data must be quantified in terms of hydrologically meaningful parameters.

Approach: We are working with three different kinds of remote sensing data, laser altimetry, synthetic aperture radar, and multispectral. The laser data was collected in transects along selected vegetation types. Complementary ground measurements were also made. The intent was to test if the laser system could accurately characterize plant height and percent cover for the plant communities of interest. The SAR data was collected by NASA. We have used it to correct for topographic surface roughness effects. The result will be a large area estimate of soil-water content. The multispectral data is from satellite. It is being used to distinguish between different kinds of vegetation and estimate the leaf area of different plant communities. Extensive ground measurements have been made to establish the actual composition.

Findings: For laser altimetry, analysis of one of the five plant communities is complete and indicates close agreement between laser and field measured values. We expect the initial analysis to be complete this August. For the SAR, we have found that :

1. The relative resolution of SAR and the USGS DEM and how to make the two compatible in terms of correcting for topographically induced backscatter effects,
2. The potential of using landscape variables other than topography, such as soils or vegetation, and recently introduced equations that describe surface roughness, to explain the observed topographic effects, and
3. The use of different techniques to estimate soil-water content on a large scale in mountainous terrain. These were evaluated using field data and a hydrologic model.

For the multispectral data, we have found that we can distinguish most plant communities reasonably well and that sophisticated approaches are not do not improve on this.

Future Plans: We will utilize this data, particularly the multispectral data, in soil-water models. In addition, we are trying to establish a quantitative link between vegetation parameters needed for modeling evapotranspiration and satellite-measured greeness indices using airborne radiometer data. This work is being done in cooperation with Utah State University.

Publications:

Goyal, S.K., Seyfried, M.S., and O'Neill, P.E. 1994. Averaging and aggregation of SAR data for reduction of noise due to topography in mountainous areas. EOS 75, 44: 238.

Goyal, S.K., and M.S. Seyfried. 1995. Removal of relief effects from AIRSAR for soil-water determination in Semi-arid mountainous areas. EOS, 46: F236.

Goyal, S.K. 1996. "Evaluation of Synthetic Aperture Radar for Soil Moisture Measurement in Mountainous Rangeland Areas". Dissertation completed with M. Seyfried as research advisor.

Ritchie J. and M.S. Seyfried, "Applications of airborne laser altimetry for measuring landscape surfaces and properties" , to be presented at the 81st meeting of the Ecological Society of America in Providence, R.I.

HISTORICAL LAND USE ON THE LITTLE WASHITA WATERSHED

Principal Scientists: Frank R. Schiebe (Retired), Robert D. Williams
Cooperating Scientist: David Waits, Patrick Starks
ARS GCRP: Res. Area: I; Prog. Element: A; Obj.: 2; Task:2
CRIS Number: 6220-13610-008-00D

Problem: Determine seasonal and long term land cover changes on the Little Washita watershed.

Approach: Spring, summer, and fall LANDSAT Multi Spectral Scanner (MSS) scenes were selected for every even numbered year beginning in 1972 with the launch of LANDSAT 1 and continuing until 1994. These scenes were purchased by NAWQL and analyzed at Oklahoma State University (C.Berry, MS thesis). All scenes were geometrically corrected and radiometrically calibrated. They were further reduced to exoatmospheric reflectance by utilizing standard exoatmospheric irradiance values and earth-sun distances.

Findings: Thirty six MSS scenes have been processed to this standard. Qualitatively there are observable long term and seasonal differences in the scenes.

Future Plans: Pending development and approval of El Reno research program: Standard vegetation indices, PVI, NDVI, Greenness, SVI, etc. will be utilized, to clarify the land cover. The changes on the Little Washita Watershed will be quantified using time series analysis.

Publication: Berry, C., Multitemporal Land Cover classification of the Little Washita Watershed using the Kauth-Thomas Greenness Vegetation . Unpublished MS thesis, Oklahoma State University, Stillwater, OK July 1995.

LITTLE WASHITA WATERSHED
GEOGRAPHIC INFORMATION SYSTEM

Principal Scientist: Patrick J. Starks,
Frank R. Schiebe (Retired)
Cooperating Scientist: Jurgen Garbrecht, Jayne Salisberry
ARS GCEP: Res.Area: I; Prog. Element: A; Obj.: 2; Task: 2.
CRIS Number: 6220-13610-008-00D

Problem: Development of Geographic Information System (GIS) coverages for the Little Washita Watershed.

Approach: GIS coverages of the Little Washita Watershed are developed in IDRISI format.

Findings: Several layers of data including DEM, soils, stream network, roads, instrument sites and subwatershed boundaries have been developed. In addition the 1994 April, August, and November LANDSAT TM exoatmospheric reflectance scenes are included. All scenes utilize IDRISI format.

Future Plans: Pending development and approval of El Reno research program: Appropriate scenes will be added as required.

USE OF REMOTLEY SENSED DATA TO ESTIMATE PLANT BIOPHYSICAL PROPERTIES

Principle Scientists: Patrick Starks, Robert Williams, Frank Schiebe
Cooperating Scientists: Karen Humes
ARS GCRP: Res. Area: I; Prog. Element: A; Obj.: 2; Task: 2
CRIS Numbers: 6220-13610-008-00D

Problem: Large-scale, physically based hydrologic models require extensive data sets for parameterization and output validation. Traditional point measurements are uneconomical to obtain and apply at large scales. Remotely sensed data offers an economical, timely and large area view of the landscape and needs to be evaluated for its usefulness in quantify vegetative characteristics (biophysical properties) which affect the partitioning of the energy and hydrologic balances.

Approach: Acquire thermal remotely sensed data over the Little Washita River Watershed (LWRW) to estimate temperatures from four typical surface types: winter wheat, alfalfa, range land and bare soil. Use optical remotely sensed data, in conjunction with neural networks and ground truth data, to obtain estimates of leaf area index (LAI) for the winter wheat, alfalfa, and range land settings.

Findings: Thermal remotely sensed data were corrected for atmospheric effects, and calculated temperatures from these data were found to be within 0.2°C of that measured for both winter wheat and range land canopies and within 1.0°C for an alfalfa canopy. The estimated surface temperature for the bare soil field was 4.8°C higher than the measured value. Leaf area indexes were estimate for three vegetative surfaces using a neural network and multi-waveband optical remote sensing. The neural network LAI estimate were found to closely match the ground truth data.

Future Plans: Pending development and approval of El Reno research program: Calculate and evaluate canopy/surface temperatures using thermal remotely sensed data obtained at several altitudes over the Little Washita River Watershed. Evaluate spatial and temporal variability of the watershed surface using the thermal data. Continue investigations of determination of leaf area index and other biophysical properties of vegetative surfaces using remotely sensed data.

Airborne laser measurement of landscape surface roughness

Principle Scientist:	Jerry C. Ritchie
Cooperating Scientist:	J.H. Everitt, K.M. Havstad, Y. Pachepsky, A. Rango, M.S. Seyfried, M.A. Weltz
ARS GCRP:	Res. Areas: I; Prog. Elements: A; Objs.: 2; Tasks: 2
CRIS Numbers:	1270-13610-004-00D, 1270-13660-005-00D

Landscape surface roughness is a key parameter for understanding many factors related to the management of water resources. The problem is that it is difficult and time consuming to measure roughness at the different scales that are useful for understanding the water movement on the landscape using current methodology. Airborne laser altimetry can provide detailed measurements for large areas of the landscape surface quickly. The laser data provide high resolution information of the micro-roughness of soil surfaces, stream channels, and gullies that could be used to estimate infiltration, evaporation, and runoff. Vegetation heights, cover, and distribution were measured and were strongly correlated with ground measurements made using line transect methods. Using fractal geometry, the complex data from the laser altimeter can be analyzed to develop parameters that can be used to quantify landscape features. Applying fractal geometry to the airborne laser data, we showed that grass-dominated landscapes had different scaling lengths and fractal dimensions than shrub-dominated landscapes. This offers the promise of new technique for analyzing laser altimeter data from aircraft and space to learn about vegetation structure and properties over large areas. This information on vegetation structure, properties, and roughness lengths will help us better understand the spatial patterns of evapotranspiration and water loss on complex landscapes and provide a basis for improved natural and agricultural landscapes.

Publications:

Ritchie, J.C. Airborne laser altimeter measurements of landscape topography. Proceedings of the Tenth Thematic Conference on Geologic Remote Sensing, pp. II-80 - II-89. 1994. (Proceedings)

Weltz, M.A., J.C. Ritchie and H.D. Fox. Comparison of laser and field measurements of vegetation heights and canopy cover. Water Resources Research 30:1311-1319, 1994.

Menenti, M. and J.C. Ritchie. Estimation of effective aerodynamic roughness of Walnut Gulch watershed with laser altimeter measurements. Water Resources Research 30:1329-1337, 1994.

Ritchie, J.C., E.H. Grissinger, J.B. Murphey and J.D. Garbrecth. Measuring channel and gully cross-sections with an airborne laser altimeter. Hydrological Processes Journal 7:237-244, 1994.

Ritchie, J.C., T.J. Jackson, R.M. Parry, K.S. Humes, J.H. Everitt, D.E. Escobar, M.R. Davis, D.M. Jacobs, D.L. Evans, D.R. Breininger, B.W. Duncan, C.R. Hinkle and M. Menenti. Remote sensing studies using an airborne laser altimeter. Proceedings of the First International Airborne Remote Sensing Conference and Exhibition Vol. II, pp.457-468, 1994. (Proceedings)

Ritchie, J.C. Airborne laser altimeter measurements of landscape surfaces: Applications to hydrology research. 1995 ACSM/ASPRS Annual Convention, Technical Papers Volume 3, Remote Sensing and Data Acquisition, pp. 639-648. 1995. (Proceedings)

Ritchie, J.C. Airborne laser altimeter measurements of landscape topography. **Remote Sensing of Environment** 53:91-96, 1995.

Ritchie, J.C., K.S. Humes, and M.A. Weltz. Laser altimeter measurements at Walnut Gulch Watershed, Arizona. **Journal of Soil and Water Conservation** 50:440-442, 1995

Ritchie, J.C. M. Menenti, and M.A. Weltz. Measurements of surface landscape properties using an airborne laser altimeter: The HAPEX-Sahel Experiment. **International Journal of Remote Sensing** 17: , 1996

Ritchie, A. Rango, W.P. Kustas, T.J. Schmugge, K. Brubaker, K.M. Havstad, B. Nolan, J.H. Prueger, J.H. Everitt, M.R. Davis, F.R. Schiebe, J.D. Ross, K.S. Humes, L.E. Hipps, M. Menenti, W.G.M. Bastiaanssen, H. Pelgrum. Jornex: an airborne campaign to quantify rangeland vegetation change and plant community-atmospheric interactions. Proceedings of the Second International Airborne Remote Sensing Conference and Exhibition Vol. I, pp., 1996. (Proceedings)

THE SEMI-ARID LAND SURFACE-ATMOSPHERE PROGRAM (FORMERLY SALSA-MEX)

Principle Scientist:	D.C. Goodrich
Cooperating Scientists:	S. Moran, S. Allen (I of H, Great Britain) D. Stannard (USGS, Denver), C. Watts (CIDESON, Hermosillo, Sonora, Mex.); J. Shuttleworth, S. Sorooshian, T. Maddock, B. MacNish (U. Ariz., Tucson, AZ), R. Avissar (Rutgers U., New Brunswick, NJ), Y. Kerr (LERTS, Toulouse, FR); L. Hipps (Utah St., Logan, UT); E. Njoku (NASA JPL, Pasadena, CA); A. Chehbouni (ORSTOM, France) NOTE: These people have contributed to the SALSA Program conceptualization and form a core group for project development.
ARS GCRP:	I.A.2.2, I.A.3.4, V.B.1.1
CRIS:	5342-13000-003-00D

Problem: SALSA constitutes a long-term monitoring and modeling effort to address pressing societal concerns related to the effects of climate- and human-induced change on the hydrological and ecological resources of semiarid regions on a seasonal to interannual time frame. The primary question that SALSA addresses is: What are the consequences of natural and human induced change on the water balance and ecological diversity of semiarid basins at event, seasonal, interannual, and decadal timescales?

Approach: The program strives to become a model for effective international, inter-agency, and university cooperation. SALSA's approach will be to determine the water, CO_2 and energy balance with the international Upper San Pedro Basin in order to answer the primary question.

Findings: An extensive effort was made to contact potential participants for the SALSA Workshop. Over one hundred people indicated interest in the workshop. Sixty-five researchers participated in the SALSA Workshop from July 31 to August 4, 1995 in Tucson, Arizona. The workshop involved a field trip to the San Pedro Basin along with three days of meetings both as a whole and in separate, disciplinary "break-out" groups. Participant comments indicated the workshop was a huge success as research plans were defined and coordinated efforts were planned. Research summaries, providing details of the work that is being proposed along with time lines and funding plans, were gathered from the workshop participants. Additionally, many multidisciplinary "sub-projects" were formed at the conference and appointed leaders of these projects were also queried for their written input. Excellent exposure was given to the program through an article published on the front page in the American Geophysical Union's, *EOS* newsletter (Wallace, Nov. 11, 1995).

Post-workshop efforts focused on further development (organizing and outlining) of the activities of the program. An INTERNET home page was developed *(http://www.hwr.arizona.edu/salsa/salsa_1.html)* to facilitate future information exchanges between participants and to advertise the program to the rest of the scientific community.

Four large proposals have been developed in direct relation to SALSA and are currently pending review. Some integrated data collection has already been initiated and more is planned as resources become available.

Future Plans: Program planning and development as well as identification of potential funding sources will continue. A SALSA Science Plan will be developed. Outreach efforts to other groups concerned with the Upper San Pedro Basin (and semi-arid basins, in general) will continue.

Title: MODELING THE RAINFALL-RUNOFF PROCESS ON SEMI-ARID RANGELANDS

Principle Scientists: F. R. Fiedler, L. R. Ahuja, J. D. Hanson, G. Frasier, J. D. Salas, J. A. Ramirez

Cooperating Scientists:

ARS GCRP: Res. Areas: 1 ; Prog. Element: A ; Objs: 3 ; Tasks: 1.

CRIS Numbers: 5402-61660-005-00D

Problem: Optimization of plant and animal production from rangelands is dependent on management of a limited water supply. Grazing intensity can affect the rainfall-runoff process. Higher grazing intensities generally lead to decreased infiltration, which decreases plant and animal production. The effect of grazing intensity on small-scale spatial variability of factors that control the rainfall-runoff process is the focus of this study.

Approach: Four experimental plots were established on the Central Plains Experimental Range in areas representative of light and heavy grazing intensities. Rainfall-runoff simulations were performed, which included measurement of outflow hydrographs and spatially variable overland flow depths and velocities. Plot microtopography was measured with a laser profilometer. Tension infiltrometers were used to estimate hydraulic conductivities of bare and vegetated spots at each grazing intensity. Soil cores were collected and will be analyzed for bulk density, organic matter, texture, porosity, and water retention characteristics. These data have been and will be continued to be used for mathematical model development and verification.

Findings: Visual observations and data analysis indicate: microtopography forces flow to occur in small channels; bare spots generally correspond to microtopographic lows, and vegetated spots to highs; vegetated spots are much more hydraulically conductive than bare spots; and heavy-grazed vegetated-spot hydraulic conductivities are significantly less than light-grazed vegetated-spot hydraulic conductivities. The first three observations dictate a conceptual modeling framework. The last observation suggests that grazing primarily reduces areal infiltration by stifling plant root growth and reducing the number and connectivity of macropores. Extensive background research has been performed to identify numerical methods which will enable infiltration and overland flow to be modeled with explicit consideration of microtopographic and infiltration spatial variability. Preliminary results show that a leapfrog finite difference scheme can handle mild microtopographic and infiltration horizontal variations. A MacCormack scheme is being tested which may be better at capturing numerical instabilities associated with larger discontinuities.

Future Plans: Different numerical methods will be investigated, until the small-scale spatial variability can be adequately incorporated. Simulations will be run to extrapolate to larger scales and test the effect of grazing intensity on plant and animal production in response to water management.

Publications:

Eckert, J.B., B.B. Baker, and J.D. Hanson. 1995. The impact of global warming on local incomes derived from range livestock systems. Agricultural Systems 48:87-100.

CHANNEL SEDIMENT TRANSPORT ALGORITHM FOR WIDELY GRADED SEDIMENT SIZE DISTRIBUTIONS

Principle Scientist: Jurgen Garbrecht and Roger Kuhnle
Cooperating Scientist: None
ARS GCRP: Res. Areas: I; Prog. Elements: A; Obj.: 3; Task: 1.
CRIS Number: 6220-13610-008-00D

Problem: Sediment transport estimation in large channel networks is difficult because existing equations generally address a narrow range of sediment sizes. In large channel networks sediment characteristics often change in downstream direction because of material sorting and spatial variability in morphology and geology. A single broad based sediment transport equation for widely graded sediment size distributions is necessary to estimate spatial patterns of sediment transport and redistribution.

Approach: Several existing and proven equations that each address a specific sediment size range are integrated into a single transport algorithm for sediments ranging from silts to gravels. The interdependence between sediment size fractions is incorporated by expressing the beginning of motion as a function of the mixture as a whole.

Findings: A sediment transport algorithm for widely graded sediment size distributions was developed. It consists of Laursen's, Yang's and Meyer-Peter and Mueller's equations and is based on transport by sediment size fraction. The interdependence between sediment size fractions was successfully represented by a relation between critical flow strength and size of the bed material for beginning of motion. The algorithm was tested against a large number of measured data, as well as for a smooth transition between successive size fractions at which transport equation changes. A systematic offset in transport rates between sand and gravels is still apparent. This offset is believed to be related to differences in separation of bed and form roughness.

Future Plans: Pending development and approval of El Reno research program: The discrepancy between sand and gravel transport rates must be eliminated by considering the bed and form roughness values in Yang's and Meyer-Peter and Muller's equations. A sensitivity analysis will be conducted to demonstrate the smooth transition between sediment size fraction for a variety of flow conditions. This will complete this research task.

Publications: (since Norman, Oklahoma, 1994 meeting)

Kuhnle, R. A. and J. Garbrecht. 1995. Measurement and Prediction of Bed Material Load on Goodwin Creek, A DEC Watershed. In: Proceedings of the 22nd Conference on Water Resources Planning and Management of the American Society of Civil Engineers: Integrated Water Resources Planning and Management for the 21st Century, Ed.: M. F. Domenica, Cambridge, Massachusetts, Vol. 2, pp. 1085-1088, May 1995.

Garbrecht, J., R. A. Kuhnle and C. V. Alonso, 1995. A Sediment Transport Formulation for Large Channel Networks. Journal of the Soil and Water Conservation, 50(5):527-529, September/October 1995.

Garbrecht, J., R. A. Kuhnle and C. V. Alonso. 1996. A Transport Algorithm for Variable Sediment Sizes: Fundamental Concepts and Equations. In: Proceedings of the 6th Federal Interagency Sedimentation Conference, Las Vegas, Nevada, Vol. 2, pp. VI-8 through VI-15, March 1996.

Kuhnle, R. A., Garbrecht J. and C. V. Alonso. 1996. A Transport Algorithm for Variable Sediment Sizes: Application to Wide Sediment Size Distributions. In: Proceedings of the 6th Federal Interagency Sedimentation Conference, Las Vegas, Nevada, Vol.2, pp. VI-1 through V-I7, March 1996.

Title: CALIBRATION AND EVALUATION OF RZWQM

Principle Scientists: L. Ahuja, H. Farahani, J. Hanson, K. Rojas, M. Shaffer

Cooperating Scientists:

ARS GCRP: Res. Areas: 1 ; Prog. Element: A ; Objs: 3 ; Tasks: 1,3.

CRIS Numbers: 5402-13660-003-00D

Problem: The USDA/ARS Root Zone Water Quality Model (RZWQM) is a comprehensive simulation model designed to predict hydrologic and chemical response, including potential for ground-water contamination, of agricultural management systems. The model is also capable of predicting the relative response of various crops (corn and soybean at this time) to changes in soil water and nutrients for different management practices. RZWQM is being applied to simulate "best management practices" (BMPs) for the Management Systems Evaluation Areas (MSEA) research sites in the midwestern states of Iowa, Minnesota, Missouri, Nebraska, and Ohio

Approach: Researchers at each site collected data suitable for calibrating and evaluating RZWQM. Generally, data collected for one of the experimental years were used for calibration and data for other years were used for evaluation. Data from irrigated and dryland sites in Colorado were also available for this exercise. The target crops for this exercise were field corn and soybean. Data generally available for the calibration process included management records, soil water and nitrogen profiles, crop yield, aboveground biomass at harvest, nitrogen content of the aboveground biomass at harvest, maximum leaf area index, and total nitrogen in the soil profile at harvest. For the model to work appropriately, we initiated an extensive calibration effort.

Findings: The model was calibrated and evaluated for corn and soybean at several sites. The model must be properly calibrated for soil water dynamics and nitrogen decomposition and leaching before it can simulate plant production. When following this procedure, the generic plant production component can be calibrated using only five parameters. Calibration errors of less then 10% of measured field values for aboveground biomass and yield were accomplished for the calibration data sets. Evaluation results were generally promising. In some cases, discrepancies occurred in predicting nitrogen or water content in the soil profile, particularly for the Missouri no-till management system, resulting in larger deviations in predicted crop biomass and yield.

Future Plans: Further work needs to be done toward: (1) improving the definition of nitrogen mineralization pools; (2) refining algorithms of plant responses to water stress; and (3) determining how best to simulate the effects of tillage treatment on soil water and nitrogen dynamics. RZWQM will be made more user-friendly by developing a graphical users interface to the program.

Publications:

Farahani, H.J. and W.C. Bausch. 1995. Performance of evapotranspiration models for maize - Bare soil to closed canopy. Transactions of the ASAE. 38(4):1049-1059.

Farahani, H.J., L.R. Ahuja, G.W. Buchleiter, and G.A. Peterson. 1995. Mathematical modeling of irrigated and dryland corn production in eastern Colorado. Clean Water-Clean Enviro.-21st Century Symp. Kansas City, MO.

Ma, Q.L., L.R. Ahuja, K.W. Rojas, V.A. Ferreira, and D.G. DeCoursey. 1995. Measured and RZWQM-predicted atrazine dissipation and movement in a field soil. Trans. ASAE 38(2):471-479.

Singh, P., K.E. Johnsen, R.S. Kanwar and L.R. Ahuja. 1995. Simulating ... drain flows using RZWQM. Int'l Symposium on Water Quality Modeling. ASAE, April 2-5, Kissimmee, Fl.

Combining Improved Snow Cover Representations and Snowmelt Algorithms for Runoff Simulation Under Conditions of Climate Change

Principle Scientists:	Albert Rango, William P. Kustas
Cooperating Scientists:	Kaye L. Brubaker, Michael Baumgartner
ARS GCRP:	Res. Areas: I; Prog. Elements: A; Objs.: 3; Tasks: 2.
CRIS Numbers:	1270-13610-002-00D

Problem: Most hydrological models, including the Snowmelt Runoff Model (SRM) include only a few climate variables as inputs that are likely to change with a new climate. A more physically-based and areally distributed SRM capable of accepting radiation, cloudiness, and albedo as well as temperature and precipitation inputs to calculate snowmelt is required to fully assess the effects of climate change.

Approach: A modular Alpine Snow Cover Analysis System (ASCAS) will be developed to monitor changes in snow cover in mountainous regions by both elevation and aspect. At the same time, SRM is being improved by the addition of a radiation-based snowmelt algorithm to make better use of the improved snow cover distributions available from satellite data and ASCAS.

Findings: ASCAS now allows data transfer between different software packages (i.e., image processing, geographic information systems, data base management, SRM, and scientific visualization). ASCAS is used to prepare snow cover data in a format for the improved SRM.

A net-radiation index has been added to SRM, which formerly used only a temperature (degree-day) index to melt snow from a basin's elevation zones. The addition of radiation to SRM allows the basin to be subdivided into hydrologic response units by general aspect as well as elevation using ASCAS. Testing of the new radiation-based SRM with measured radiation from the small W-3 research basin in Vermont was successful. In 2 of 6 test years, goodness-of-fit statistics improved with the new radiation based approach and remained about the same in the other years. Testing of the new model on the larger Dischma basin in Switzerland in the climate change mode showed that the snowmelt calculation is very sensitive to not only temperature and precipitation changes, but also to cloudiness. The prevalence of thinner or thicker clouds after climate change can have as an important effect as a change in temperature. It is now possible to calculate the hydrologic response to climate change in snowmelt regions when the climate change scenario includes one or more of the following climate variables: temperature, precipitation, cloud amount, cloud type, radiation, or snow cover extent.

Future Plans: Final refinements are being made to the various ASCAS modules. The new improved SRM needs to be linked to ASCAS. The new radiation-based SRM will be tested next on large water supply basins in the western U.S. where the radiation melt component will need to be calculated based on commonly available radiation and cloud data or from time of year, latitude, and topographical information. Documentation will be written to assist users in applying the new SRM.

Publications:

Baumgartner, M. F. And Rango, A., 1995. A microcomputer-based alpine snowcover and analysis system, Photogrammetric Engineering & Remote Sensing, 61(12), 1475-1486.

Rango, A. And Baumgartner, M. F., 1996. Data transfer, necessary interfaces, and applications in a modular snow hydrology modelling system, Remote Sensing and GIS for Site Characterization: Applications and Standards, ASTM STP 1279, American Society for Testing and Materials, San Francisco, pp. 38-42.

Rango, A., 1994. Recent advances in the Snowmelt Runoff Model (SRM), Proceedings of the Second International Workshop on the Applications of Remote Sensing in Hydrology, National Hydrology Research Institute, NHRI Symposium No. 14, Saskatoon, Saskatchewan, pp. 201-210.

Brubaker, K., Rango, A., and Kustas, W., 1996. Incorporating radiation inputs into the Snowmelt Runoff Model, Hydrological Processes, 10(10), 12 pp.

Brubaker, K. And Rango, A., 1996. Response of snowmelt hydrology to climate change, Journal of Water, Air, and Soil Pollution. In Press.

CLIMATE CHANGE OVER THE CONTINENTAL UNITED STATES
BASED ON 40 YEARS OF CLIMATE DATA

Principle Scientist: Arlin D. Nicks
Cooperating Scientist: None
ARS GCRP: Res. Areas: I; Prog. Elements: A; Obj.: 4; Task: 2, and Task: 3.
CRIS Number: 6220-13000-005-00D

Problem: Global Circulation Models (GCM) estimates project increases in global mean annual temperature of 1 to 3 °C by the year 2050. GCM estimates are based on spatial grid resolutions of 4 to 7 degree latitude and longitude, which are too large to be of much use in modeling most of the ARS watersheds. In the southern Great Plains of the U.S. annual precipitation varies up to 750 mm from the west to the east across a GCM size grid. Methods and techniques are needed to project downward from the GCM, to climate station grid, to watershed scales of less than 100 km ^{2}. Better description of expected seasonal changes in temperature and precipitation are need at regional scales to formulate scenarios of climate change that can be utilized by water resource models to estimate the impacts of Global Change.

Approach: As part of the WEPP Modeling effort a database of over 1000 National Weather Service climate stations were extracted from the archives of the National Climatic Data Center. These selected stations spaced on a 1 x 1 degree grid were analyzed and parameters for the CLIGEN weather generator calculated. CLIGEN was then used to estimate the missing daily precipitation and maximum and minimum temperature. Daily, monthly, and annual time series were then constructed at each station. For most of the stations (approximately 700), records existed for the period from 1950 to 1990. Time series analyses were conducted on these station to determine their temporal and spatial dependence. Monthly, seasonal, and annual trends for each station were calculated and then plotted using computer contouring methods.

Findings: Results of the time series plots for this 40 year period showed that trends in maximum annual temperatures have decreased in the south, east, and southwestern regions of the U.S. Minimum temperatures trends have increased in northwestern regions and decreased in the southeastern regions of country. Average annual mean temperatures have, in general, increased north of a line from Lake Michigan to the Mexican border in southeastern Arizona and decreased southeast of this line to the Florida peninsula. Most changes in annual mean temperatures were associated with changes in minimum temperatures. Annual precipitation trends indicate an

increased of 1 to 8 mm/year starting in the northwest in the states of Washington and Oregon and increasing to the gulf coast in Mississippi and Alabama. According to these trends nearly 90 per cent of the U.S. have experienced an increase in precipitation during this 40 year period.

Future Plans: Aggregation of spatial data to the GCM grid scale will be completed and temporal and spatial differences will be determined between grid sizes.

Publications: (since Norman, Oklahoma, 1994 meeting)

Nicks, A. D., Lane, L. J., Gander, G. A., and Manetsch, C. 1993. Regional analysis of precipitation and temperature trends using grided climate station data. In (Wang, S. S. Y., Ed), Advances in Hydro-Science & Engineering. The University of Mississippi. 1(A):497-502.

Nicks, A.D. Spatial and temporal precipitation Characteristics over a large gaged network. Journal of Soil and Water Conservation. 50(5):443-445. 1995

Nicks, A.D. Spatial and temporal comparisons of rain gage network and climate stations data. ARS Climate and Weather Research Workshop Proceeding (In Press) 1995.

Nicks, A.D. and Gander, G. A. Spatial analyses of weather generator parameters. ARS Climate and Weather Research Workshop Proceeding. (In Press) 1995

EVALUATING ENSO EFFECTS ON PRECIPITATION

Principal Scientist: D.C. Goodrich, T.O. Keefer
Cooperating Scientists: D. Davis, G. Johnson, D. Woolhiser
ARS GCRP: I.A.4.4, I.A.5.1, I.A.5.2
CRIS Numbers: 5342-13610-005-00D

Problem: Current daily precipitation models underestimate the variances of observed monthly, seasonal and annual precipitation occurrence and amount. Effects of non-periodic large-scale atmospheric forcings (e.g. ENSO) have been shown to be detectable in daily precipitation signals and may be significant factors in seasonal and interannual variability. Whereas individual raingages have been used previously, dense raingage networks may enhance the detection of connections between remote forcings and localized precipitation with respect to elevation, region, and season.

Approach: Seasonally-varying daily-precipitation model parameters under influence of atmospheric forcings are optimized using maximum likelihood techniques. SOI perturbations to model parameters are evaluated for significant effects for southwest U.S. and northern Mexico stations. Sequences of modeled daily precipitation with and without SOI perturbations are evaluated using statistical hypothesis testing and an objective criterion.

Findings: SOI perturbations have statistically significant impacts on daily-precipitation model parameters which result in statistically significant improvements in modeled daily precipitation. SOI effects during winter (November through April) are to increase modeled daily precipitation occurrence and amount, and increase the variance of monthly precipitation totals over simulated precipitation without SOI perturbations for one Arizona and two Sonora, Mexico stations. The Nash-Sutcliffe efficiency statistic is increased when SOI perturbed model results are compared to observed precipitation at the Arizona station, indicating model improvement.

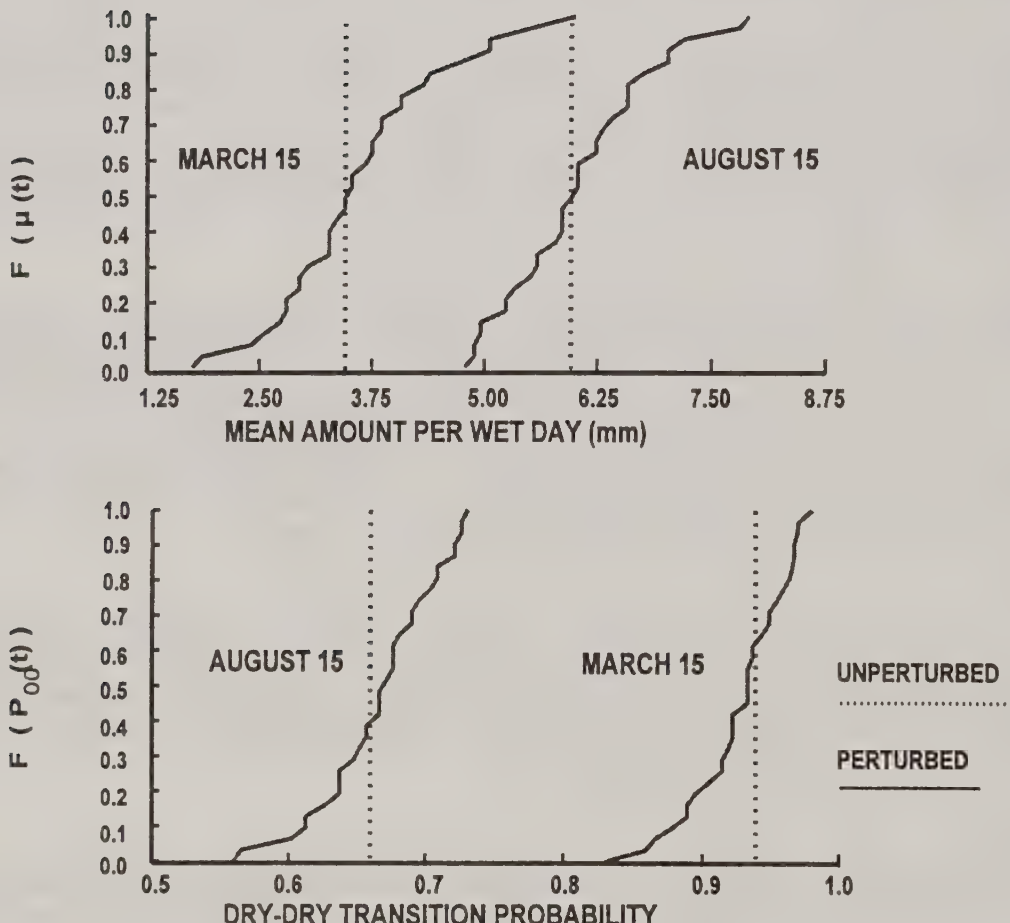
Future Plans: Evaluate the differences between SOI perturbed model parameters optimized for an individual raingage and those of a dense raingage network, at watershed and basin scales, incorporating elevation and season attributes, for distinct U.S. regions. Incorporate algorithms for SOI effects into weather generators. Exploit the apparent lead-time between SOI and local precipitation for improved conditional simulations.

Publications:

Keefer, T.O. and D.C. Goodrich. 1995. Evaluating Southern Oscillation seasonal effects on parameters of a daily precipitation model. Abstract. *EOS Trans.*, AGU, vol. 76, no.46.

Notes:

The responses of monthly-varying parameters of a Markov chain-mixed exponential daily precipitation model to perturbations of the Southern Oscillation Index (SOI) were evaluated. SOI perturbations to model parameters cause up to 15% deviations from the unperturbed dry-dry transition probability and up to 88% deviations from the unperturbed mean amount per wet day. The variances of simulated monthly total precipitation accumulated depth and number of wet days from perturbed models are significantly larger than those of an unperturbed model during months for which the SOI has a significant impact on daily precipitation.



TIME SERIES ANALYSIS OF DATA FOR RAINGAGE NETWORKS

Principle Scientists:	L. Lane, M. Nichols
Cooperating Scientists:	R. Gibbons
ARS GCRP:	I.A.4.3
CRIS Numbers:	5342-13610-005-00D

Problem: The ability to evaluate shrubland ecosystem dynamics in a changing environment requires a historical perspective and quantitative analysis of one of the primary ecosystem inputs, precipitation.

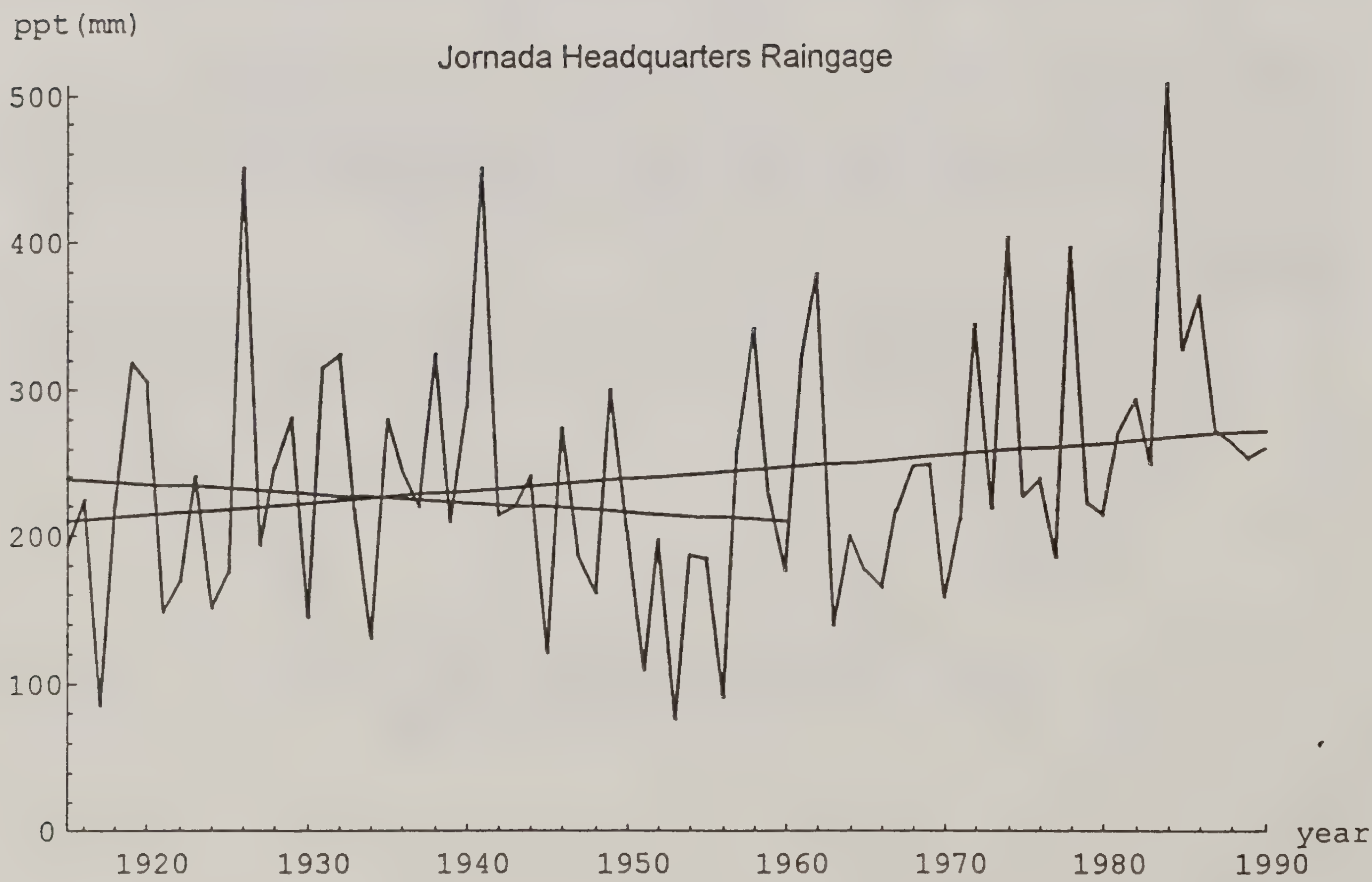
Approach: Historical time series of precipitation data collected from 25 raingages on the USDA Jornada Experimental Range since early 1915 are examined. Time series analysis are conducted to test for trends, autocorrelation, and periodicities in the data and establish an association between mean annual precipitation and time. These results will be compared with long-term precipitation data from the USDA Walnut Gulch Experimental Watershed and records from the Santa Rita Experimental Range in Southeastern Arizona to determine if regional patterns exist in annual precipitation. Additional time series analysis will be performed to determine if shifts in seasonal patterns in precipitation exist and if the patterns are similar at the three location.

Findings: The analysis of historic records can reveal increasing annual precipitation, decreasing annual precipitation, or no trend in annual precipitation depending upon the record segment analyzed. Caution must be exercised in attempting to assign either natural variations in weather and climate or rangeland use and management practices as the cause of changes in vegetation over time.

Publications:

Nichols, M. N., L. J. Lane, and C. Manetsch. 1993. Analysis of Spatial and temporal precipitation data over a densely gaged experimental watershed. *Management of irrigation and drainage systems*. Symposium sponsored by: Irrigation and Drainage Div./ASCE, July 21-23, Park City, Utah. Pg. 440-447.

Notes:
The analysis of historic records can reveal an increasing trend in annual precipitation or a decreasing trend in annual precipitation depending upon the record segment analyzed.



Title: Characterization and Modeling of Precipitation and other Meteorological Elements at the Watershed Scale

Principal Scientists: Greg Johnson, Clayton Hanson

ARS GCRP: **Res. Areas:** Climate and Hydrology
Prog. Element: I
Objectives: 4 **Task:** 4 (Initiated February 1994)

CRIS Number: 5362-13610-004-00D

Problem: Mesoscale atmospheric models are already being used in operational weather forecasting and for providing inputs to hydrologic models, but remain largely untested at scales and domains critical for important hydrologic processes.

Approach: Use models such as the Regional Atmospheric Modeling System (RAMS) to investigate scale effects, land-atmosphere interactions, initialization procedures, and algorithms for estimating precipitation, wind and other meteorological elements over watersheds up to 10,000 km^2 in size. Focus first on significant winter hydrologic events in the Interior Pacific Northwest using the data base from the Reynolds Creek Experimental Watershed (RCEW).

Findings: RAMS simulations of a significant rain-on-snow event at the RCEW in March, 1993 fairly well mimicked actual observations of precipitation, wind speed and direction, and temperature. However, simulation results, such as accumulated precipitation, were shown to be strongly dependent on grid resolution and the data set chosen for initialization. A grid resolution of approximately 1 km produced simulated amounts that most closely corresponded to observed values.

Precipitation from this storm was principally caused by orographic mechanisms. Initial fields of atmospheric moisture and wind flow were found to be extremely important in determining accumulated precipitation amounts in the simulations. In this March case, data from a nearby radiosonde site used for RAMS initialization resulted in better simulations of watershed precipitation than did gridded (2.5 degree square) fields from National Meteorological Center analyses.

Future Plans: Several more hydrologically-important winter storms will be simulated over the RCEW using RAMS, to identify if results from the March, 1993 are consistent. An intercomparison of RAMS with several other atmospheric models for the March case will be conducted. Land cover and other surface effects will be investigated.

Publications:

Johnson, G.L., P. J. Dawson and D. Wang. 1996. Derivation of wind and precipitation fields at the watershed scale using two atmospheric models. In: Proc. ARS Workshop on Weather and Climate Research, Denver CO, July 1995. 10 pp.

Dawson, P., G.L. Johnson, C.L. Hanson and D. Wang. 1996. Meteorological studies in a mountainous watershed. In: Proc. 7th Intl. Symp. on Measurement and Modeling of Environmental Flows, IMEC&E '95, San Francisco CA, Nov. 12-17, pp. 147-152.

Title: **Spatially-Relevant Stochastic Weather Simulation Model Development**

Principal Scientists: **Greg Johnson, Clayton Hanson**

Cooperating Scientist: **Clarence Richardson**

ARS GCRP: **Res. Areas:** Climate and Hydrology
Prog. Element: I
Objectives: 5 **Task:** 1

CRIS Number: 5362-13610-004-00D

Problem: Both the estimation of weather generator parameters and the capability of these models to accurately replicate the real weather and climate in regions with significant climatic heterogeneity presently are quite poor.

Approach: Derive GEM (Generation of weather Elements for Multiple applications) model parameters (for precipitation and temperature, initially) and distribute these spatially using the PRISM (Parameter-Regressions on Independent Slopes Model) model. Develop an interactive system whereby relevant scenarios can be derived for any 2 km resolution location using the modified GEM model.

Findings: This approach has been applied in a test over an approximate 60,000 km^2 area of southern Idaho and southeastern Oregon. More than 65 GEM precipitation and temperature parameter maps were derived using PRISM on an 80 station data base. Some of these were SNOTEL sites which had much shorter periods of record compared to the other stations (5-8 years versus 30 years), as well as some different measurement methods. This necessitated the creation of special techniques for processing these data before GEM parameters could be deduced from them.

Software was written to allow point-and-click extraction of GEM parameters from PRISM-derived maps (digital data layers), using TCL toolkit software on the UNIX operating system. Preliminary analyses indicate accurate weather scenarios for any 2 km pixel in this region can be derived. Summary statistics compare favorably to climate statistics at random locations, and cross-validation statistics also confirm the potential accuracy of this method. Special techniques for mapping highly discontinuous and microclimatically-driven parameters such as mean minimum temperature were developed and will be refined

Future Plans: Apply and test this methodology over portions of the Mid-Atlantic/Appalachian region of the U.S. Continue to refine techniques for distributing "difficult" parameters. Develop and test methods of deriving parameters from summarized and more readily available climatic data. Enhance the GEM code to generate other elements, such as dewpoint and wind, and map these parameters using PRISM. Develop and test methods for temporally disaggregating generated daily values from GEM into hourly time increments.

Publications:

Johnson, G.L., C.L. Hanson, S.P. Hardegree and E.B. Ballard. 1996. Stochastic weather simulation: Overview and analysis of two commonly used models. J. Appl. Meteor. (In Press)

Johnson, G.L., C.L. Hanson, C. Daly, G. Taylor and C.W. Richardson. 1996. The development and testing of a spatially-relevant stochastic weather simulation model. In: Proc. ARS Workshop on Weather and Climate Research, Denver CO, July 1995. 10 pp.

Johnson, G.L., C.L. Hanson, Y.Y. Lu and C.W. Richardson. 1996. Spatially relevant stochastic weather simulation model development for biological and hydrological applications. In: Proc., 22nd AMS Conf. on Agr. and For. Meteor., Atlanta GA. pp. 369-372.

WEATHER GENERATION WITH NON-STATIONARITY IN GENERATED TIME SERIES

Principle Scientist: Arlin D. Nicks
Cooperating Scientist: None
ARS GCRP: Res. Areas: I; Prog. Elements: A; Obj.: 5; Task: 1.
CRIS Number: 6220-13000-005-00D

Problem: Global Circulation Models (GCM) estimates project increases in global mean annual temperature of 1 to 3 °C by the year 2050. GCM estimates are based on spatial grid resolutions of 4 to 7 degree latitude and longitude, which are too large to be of much use in modeling most of the ARS watersheds. In the southern Great Plains of the U.S. annual precipitation varies up to 750 mm from the west to the east across a GCM size grid. Methods and techniques are needed to project downward from the GCM, to climate station grid, to watershed scales of less than 100 km^2. Better description of expected seasonal changes in temperature and precipitation are need at regional scales to formulate scenarios of climate change that can be utilized by water resource models to estimate the impacts of Global Change.

Approach: The CLIGEN weather generator was modified to incorporate non-stationarity in to generated times series. Monthly mean daily precipitation, mean maximum and minimum temperatures, solar radiation, and wet-wet and dry-wet day probabilities trends (element units/year) can be user specified by month or entered from calculated trend values. The stochastic time series calculated in CLIGEN then have the trend line slope added to the monthly mean parameter value resulting in a time series that increases or decreases according to the trend.

Findings: Four different climate change scenarios have been applied to the Little Washita river watershed in central Oklahoma using stochasticly generated data. Using the monthly trends calculated from climate stations near the watershed and the observed watershed parameters, the SWRRB model was then used to estimate the impacts of climate change on water and sediment yield. Model results indicated that with an increase of 16 per cent in precipitation and a 13 per cent increase in mean temperature, annual water yield, sediment yield and evapo-transpiration increased up to 73, 103, and 8 per cent respectively.

Future Plans: None.

Publications: (since Norman, Oklahoma, 1994 meeting)

Nicks, A. D., Lane, L. J., Gander, G. A., and Manetsch, C. 1993. Regional analysis of precipitation and temperature trends using gridded climate station data. In (Wang, S. S. Y., Ed), Advances in Hydro-Science & Engineering. The University of Mississippi. 1(A):497-502.

Savabi, M. R., Arnold, J. G. and Nicks, A. D. 1993. Impact of global climate changes on hydrology, soil erosion,and crop yield. In: Eckstien, Y. and Zaporozec, A.(ed.) Proceedings 2nd US/CIS Joint Conference on Environmental Hydrology and Hydrogeology: Global and Regional issues in Environmental Hydrology. Water Environment Federation, Alexandria, VA. pp.3-18.

Nicks, A. D. 1993. Estimating water resources of a mixed land use basin under changing climate and environment. International Conference on Environmentally Sound Water Resources Utilization. Bangkok, Thailand. November 8- 11, 1993. In Tingsanchai, T. (ed.) Proceeding of the International Conference on Environmentally Sound Water Resources Utilization. Vol. 1, II-8-17.

Nicks, A. D. and Gander, G. A. 1994. Estimating the impacts of Global Change on erosion with stochastically generated climate data and erosion models. In Olive, L.J., et al. (eds) Variability in Stream Erosion and Sediment Transport. IASH Publication No. 224, pp. 473-478.

Nicks, A.D., Williams, R.D. and Williams, J.R. Regional analysis of erosion from agricultural fields using global change scenarios. IASH Symposium on Erosion and Sedimentation: Global and Regional perspectives. Exeter, UK. (In Press) 1995

Ecololgical Systems and Dynamics
Global Climate Change Effects on Rangeland Ecosystems
Southern Plains Range Research Station, Woodward, OK

Principal Scientists: Phillip L. Sims and Jim Bradford

Cooperating Scientists: Gary Coughenour, Derek Bailey, Herman Mayeux, Bill Dugas, Bill Emmerich, Al Frank, Marshall Haferkamp, Kris Havstad, Jack Morgan, Nick Saliendra, Jerry Schuman, Tony Svejcar, John Walker

ARS GCRP: Res. Areas: **I**	Prog. Elements: **B**	Objs: **1**	Tasks: **2**
	Prog. Elements: **C**	Objs: **2, 3**	Tasks: **2, 1**

CRIS Numbers: 6216-26130-001-00D

Problem: 1) Predicted increases in atmospheric CO_2 and changes in temperature and precipitation patterns may cause significant changes in the growth of rangeland plants and their response to grazing animals. Few physiologically based models are available which can be used to predict and plan for these changes. 2) The relationship between biomass production and CO_2 and H_2O flux from U.S. rangelands are fundamental eco-physiological phenomenon which have not been quantified on a continuous season-long basis. Since rangelands are so extensive, an integrated, multi-site project is necessary in order to make large scale estimates of these fluxes.

Approach: 1) Robust, physiologically based rangeland plant growth simulation models will be used to advance the integration and application of current research information concerning plant/animal interactions in range systems. 2) The Bowen ratio energy balance method will be used to estimate CO_2 and H_2O flux from rangelands and compared to detailed range plant production measurements.

Findings: 1) The RaPPs and GRASS plant growth models were found to be complimentary in structure. RaPPs had a robust leaf gas exchange submodel while GRASS had more developed perenniality and grazing submodels. Integration of the two models resulted in a more robust and testable simulation model. Testing of the integrated model using data for *Bothriochloa caucasica* and *Tripsacum dactyloides* showed that errors in predicting stomatal conductance were reduced by 50%. The integrated model (RaPPs/GRASS) predicted that photosynthesis would increase by 8 to 24% and stomatal conductance would decrease by approx. 30% if ambient CO_2 increased from 350 to 700 ppm. 2) Preliminary results show general agreement between CO_2 flux and biomass production. During the period of 1 Apr. 1995 to peak standing crop, brush-free rangeland was estimated to have fixed 400 g CO_2 / m^2. Brush-dominated rangeland, which had a larger component of cool-season plants was found to have more fixation earlier in the season and fixed approximately 360 g CO_2 / m^2.

Future Plans: 1) Continue development of the RaPPs/GRASS model. 2) Compare the CO_2 and H_2O flux of brush-dominated and brush-free sand hills rangeland for approximately two more years. If the technology is deemed appropriate, the Bowen ratio system will be used for further rangeland treatment comparisons and/or for measurements on improved pasture grass monocultures.

Publications:

Berg, W. A. and Sims, P. L. 1995. Nitrogen fertilizer use efficiency in steer gain on Old World bluestem. J. Range Manage. 48:465-469.

Dougherty, R. L, Bradford, J. A., Coyne, P. I., and Sims, P. L. 1994. Applying an empirical model of stomatal conductance to three C-4 grasses. Agric. and For. Meteorol. 67:269-290.

Bailey, D. W., Sims, P. L. and Bradford, J. A. 1996. Utilization and regrowth of eastern gamagrass (*Tripsacum dactyloides* (L.)L.). p. 31-32. In N. E. West (ed.) Rangeland a sustainable biosphere. Proc. Vth Int. Rangeland Conf. Soc. Range Manage. Denver.

Sims, P. L., Coughenour, M. B., Bailey, D. W. and Bradford, J. A. 1996. Evaluation of two gas exchange mathematical simulation C_4 grasses. p. 514-515. In N. E. West (ed.) Rangeland a sustainable biosphere. Proc. Vth Int. Rangeland Conf. Soc. Range Manage. Denver.

Carbon Dioxide Flux of Sagebrush Steppe Vegetation

Ray Angell and Tony Svejcar
Northern Great Basin Exp. Range
Burns, OR

ARS Global Change Research Program: See description of Research Areas, Program Elements, Objectives and Tasks in Appendix A.

Research Areas:	I	III
Program Elements:	B	A
Objectives:	1	3
Tasks:	2, 4	4

CRIS Number: 5360-11630-003-00D

Problem

The Intermountain Sagebrush Ecoregion encompasses about 130 million acres in Nevada and parts of Utah, Idaho, Oregon, Washington, and California. This represents about 6% of the total U.S. land area. We have limited information on the role and importance of the sagebrush steppe in carbon (C) sequestration. Because plant growth is often stimulated when CO_2 concentration rises, some have hypothesized that increased allocation of C belowground will result in increased soil C storage. Currently there is a paucity of quantitative information available on C cycling for this region. Owing to the extensiveness of the region, even small fluctuations in net C flux are important.

Approach

This project is part of a cooperative research effort among 11 ARS locations aimed at resolving ambiguities and uncertainties regarding CO_2 flux on North American grasslands. This portion of the effort is focused on the annual CO_2 exchange on an *Artemisia tridentata var. Wyomingensis/Stipa thurberiana* site. This vegetation type is common in the northern Great Basin. We intend to incorporate prescribed fire after collection of baseline data.

Two sites have been selected for study. Carbon flux is being measured at two scales. We designed a 1 m^3 chamber to measure net exchange rates at the canopy scale. These measurements are then supplemented with simultaneous soil respiration determinations. At the landscape scale, Bowen ratio/energy balance techniques were begun in 1995 and provide continuous estimates of CO_2 and H_2O fluxes.

Findings

The project was initiated in 1995 and became fully implemented in 1996. Preliminary data summaries have been conducted and indicate that the large chamber will work well in this vegetation type.

Raw chamber data from 12 June, 1995 had an average 3.8 $\mu mol \cdot m^{2} \cdot s^{-1}$ downward CO2 flux, while concurrent BREB estimates on a similar site were about 3.4 $\mu mol \cdot m^{2} \cdot s^{-1}$. These values are two independent measures of the same plant and soil processes, so the close agreement is encouraging. Bowen ratio data and chamber data both indicate that flux magnitudes are generally low, and strongly influenced by timing of soil temperature increase in spring as well as soil water depletion.

Future Plans

Objectives of planned CY 1996 experiments are to determine the CO_2 flux rates on two similar sagebrush steppe sites. After collection of baseline data, one of the sites will be treated with a prescribed burn. We will measure CO_2 and water flux and quantify effects of prescribed fire on CO_2 and H_2O exchange rate. These experiments will provide new and important data which can be utilized in current and developing models. The information will also be utilized by policy makers interested in rangeland management.

Publications

Angell, Ray and Tony Svejcar. 1996. Carbon flux measurement on southeast Oregon range and meadow vegetation. Abstr. Soc. for Range Manage. 49th Annual Meeting. p 3.

CARBON DIOXIDE AND MOISTURE FLUXES ON NORTH AMERICAN GRASSLANDS

Principle Scientists: W. E. Emmerich
Cooperating Scientists: R. Angell, J. Bradford, W. Dugas, A. Frank, M. Haferkamp, J. Morgan, N. Saliendra, J. Schuman, P. Sims, T. Svejcar, and J. Walker
ARS GCRP: I.B.1.2
CRIS Numbers: 5342-13610-005-00D

Problem: The calculated release of CO_2 from anthropogenic sources is more than double the measured annual increase in atmospheric CO_2. Rangelands have been suggested as a sink for the CO_2 because of their large geographical extent, but there is no effort to assess CO_2 fluxes across the range of environmental biomes where rangelands exists.

Approach: ARS scientists at various locations will cooperate in making CO_2 and moisture flux measurements across western regions of the U.S. with widely contrasting rangeland vegetation and species composition. At each location, carbon and moisture dynamics will be measured on grasslands typical of the area and on areas of particular interest; for example, areas under grazing or burning practices that could influence the fluxes will be sampled.

Findings: This is a new research project for the Tucson location. Flux measuring equipment was installed in May 96 on a native grassland and brush dominated sites to compare strongly contrasting vegetation types.

Future Plans: Flux measurements will be taken for, minimally, two years to evaluate carbon pools in soil and biomass. Water balance budgets will also be evaluated with precipitation, surface runoff, and evapotranspiration.

Agricultural management effects on soil and atmospheric quality

Principal Scientists: J.W. Doran, A.R. Mosier and J.F. Power
Cooperating Scientists: A. Kessavalou, G.L. Hutchinson and R.A. Drijber

ARS GCRP: Res. Areas: I (IV); Prog. Elements: B(A); Objs:2,3 (2); Tasks: 3 & 5; 5,6,7 (1)
Cris Number: 5440-12000-007-00D
5440-12000-007-01S

Problem: Recently, we demonstrated the interrelationship between CO_2, N_2O and CH_4 flux and selected soil quality indicators, as influenced by intensive soil and crop management practices. However, the immediate effects of tillage and wetting on these gas fluxes are largely unknown and need to be studied to better understand and predict the impact of agricultural practices on soil and atmospheric quality.

Approach: Trace gas flux measurements using surface chambers were made at different time intervals for 15 days following tillage and wetting from long term wheat-fallow rotation plots under no-till and sub-till in the fall of 1995 and no-till, sub-till and plow in the spring of 1996. In addition, soil quality indicators such as soil temperature (5 cm) and water-filled pore-space (WFPS), pH, EC and NO_3 in the top 30 cm (0-7.6, 7.6-15 and 15-30 cm) were determined at each gas sampling time.

Findings: Trace gas flux measured in fall 1995 is summarized here. Pulses of CO_2, N_2O and CH_4 fluxes changed immediately following tillage and wetting. Overall, mean CO_2 and N_2O fluxes ranged from 4.6 to 29.7 kg C ha^{-1} d^{-1} and -0.15 to 3.47 g N ha^{-1} d^{-1}, respectively, while the CH_4 uptake averaged between 1.7 to 12.2 g C ha^{-1} d^{-1} across treatments. Immediately following sub-tillage, CO_2 and N_2O fluxes increased as high as 69 and 92 %, respectively, and remained high for about 8 hr. Further, 24 hr after wetting the soil with 5.1 cm water, about 70 and 380 % increase in CO_2 and N_2O flux, respectively, occurred under sub-till and remained elevated throughout the study period. In general, sub-tillage led to a significant increase in CH_4 uptake. About 1.9 times increase in CH_4 uptake was observed 16 hr after sub-tillage. However, wetting led to a reduction in soil CH_4 uptake. About 76 % reduction in CH_4 uptake was observed 24 hr after wetting under no-till and sub-till and the effect remained throughout the study period.

Soil WFPS and NO_3 in the top 7.6 cm ranged from 25 to 80 % and 11 to 30 kg NO_3-N ha^{-1}, respectively. Soil pH and EC in the top 30 cm ranged between 6.2 to 7.2 and 0 to 0.3 dS m^{-1}, respectively. Soil temperature (5 cm) was between 6.5 to 30 ° C. Soil temperature, WFPS, pH strongly influenced trace gas flux, while EC served as a reliable tool to predict soil NO_3.

Given the expected frequency of tillage and rainfall at this site, the pulses of trace gas fluxes that occurred following tillage and wetting events could cause roughly 20 and 35 % increase in annual CO_2 and N_2O fluxes, respectively, and 42% reduction in annual CH_4 uptake. However, mean annual trace gas fluxes under this ecosystem were lower than from irrigated and fertilized ecosystems.

Future Plans: Spring 1996 samples are being analyzed. Effects of tillage and wetting on CO_2, N_2O and CH_4 flux will be modeled as a function of soil quality and its contribution to global trace gas budget will be evaluated. Results will be published in a refereed journal.

Publications (1996)

Doran, J.W., A. Kessavalou, G.L. Hutchinson, M.F. Vigil, and A.D. Halvorson. 1996. Influence of cropping/tillage management on soil fertility and quality of former CRP land in the central high plains. Proceedings of the Great Plains Soil Fertility Conference. March 5-6, 1996, Denver, Colorado.

Hutchinson, G.L., M.F. Vigil, J.W. Doran, and A. Kessavalou. 1996. Large scale modeling of soil-atmosphere NO_x exchange. Presented at the international workshop on NO_x emission from soils and its influence on atmospheric chemistry. March 4-6, 1996, in Tsukuba, Japan.

Kessavalou, A., J.W. Doran, A.R. Mosier, and R.A. Drijber. 1996. Carbon dioxide, nitrous oxide and methane flux following tillage and wetting. Agronomy Abstracts. 1996. Annual meeting in Indianapolis, IN.

Kessavalou, A., A.R. Mosier and J. W. Doran. 1996. Trace gas fluxes under grassland and wheat-fallow systems in the Central High Plains of Nebraska (under preparation for the Global Biogeochemical Cycles).

Kessavalou, A., J.W. Doran, W.L. Powers and J.H. Qian. 1996. Bromide and ^{15}N tracers of nitrate leaching under irrigated corn in the central Nebraska. J. Environ. Qual. 25 (5).

Qian, J.H., J.W. Doran, K.L. Weier, A.R. Mosier, T.A. Peterson, and J.F. Power. 1996. Soil denitrification and nitrous oxide losses under corn irrigated with high nitrate groundwater. J. Environ. Qual. (Accepted April 1996).

Title: Carbon sequestration in seeded pastures, native pastures, and conservation tillage systems.

Principle Scientists: A. B. Frank, A. D. Halvorson, D. L. Tanaka, and B. J. Wienhold

ARS GCRP: Res. Areas I; Prog. Elements: B; Objs: 1; Tasks: 2

CRIS No. 5445-21000-005-00D; 5445-12130-003-00D

Problem: The influence of management on soil carbon and N changes in the Northern Great Plains is not defined for native grasslands, seeded pastures, and conservation tillage systems.

Approach: Two native pastures managed since 1916 and CRP areas seeded in 1986 were sampled. The 65-acre cropping systems-conservation tillage study was sampled to determine the effects of cropping sequence, tillage, and N applications over a 12-year period on soil carbon, nitrogen, and soil property changes.

Findings: Soil organic carbon content avg 7.2, 6.4, and 7.4 kg m^{-2} to 30.4 cm soil depth and 14.1, 11.7, and 14.0 kg m^{-2} to 106.7 cm soil depth for the exclosure, moderately grazed, and heavily grazed treatments, respectively. Heavy grazing did not reduce soil carbon when compared to the exclosure. The increase in blue grama, from 25% in 1916 to 86% in 1994 in the heavily grazed pasture, probably accounted for maintenance of soil carbon at levels equal to the exclosure.**Soil C contents for conventional, minimum, and no-till in a spring wheat-fallow system was +2%, -8%, and -13%, respectively in 1991 relative to 1983 levels. Continuous cropping with conventional tillage decreased soil C by -2.5%, but increased soil C by +5.6% and +10.1% for minimum and no-till, respectively.

Future Plans: The historical pasture study is completed. The CRP areas were sampled in 1988 and 1992, and will be sampled again in 1996.**The conservation tillage system plots will be sampled in 1996 after 12 years of cropping.**A study was initiated in the fall of 1994 to determine the best techniques and methods for conversion of CRP land to crop production while controlling soil erosion and maintaining positive influences of permanent vegetative cover.**We are evaluating tillage practices by enumerating fungi, bacteria, and actinomycetes; quantifying microbial biomass, microbial biomass C, and microbial biomass N; measuring the amount of potentially mineralizable N; and conducting a litter decomposition study.

Publications:

Frank, A. B., D. L. Tanaka, L. Hofmann, and R. F. Follett. 1995. Soil carbon and nitrogen of Northern Great Plains grasslands as influenced by long-term grazing. J. Range Manage. 48:470-474.

Black, A. L. and D. L. Tanaka. 1996. A conservation tillage-cropping systems study in the northern Great Plains of the USA. *In:* Paul, E. and C. V. Cole (eds.) Soil Organic Matter Sequestration Book. -----

SOIL-C STORAGE WITHIN SOIL-PROFILES OF THE HISTORICAL GRASSLANDS OF THE USA

R. F. Follett and E. A. Pruessner - Co-investigators:
J. Kimble[1] and S. Samson[1]
Research Area I, Program Element B, Objective 1, Task 3.

PROBLEM: Large reserves and the potential to sequester large amounts of carbon (C) in soils exists in the historical grasslands (HG) of the USA. These soil are important as a source-sink in global C cycling. Large areas within the HG region are converted from cropland to the Conservation Reserve Program (CRP). Research indicates that CRP enhances C sequestration, but the magnitude is uncertain as is the importance of C gains or losses at deeper soil-profile depths. Another consideration is that CRP contracts are beginning to expire; millions of hectares of CRP land may return to production. Thus, much of the C that the CRP program helped sequester is at risk to being recycled back to the atmosphere as CO_2.
APPROACH: A collaborative effort is initiated with the National Soil Survey Laboratory (NSSL) of the NRCS in Lincoln, NB to collect detailed soil-profile measurements. Careful use of these data, with STATSGO or other data bases, will allow regional estimates of soil-C storage in the HG and the influence of management (cropped vs. CRP vs. native grassland). Soils are being sampled by soil horizon from pits dug to $\geq$2m depth at typical sites along precipitation and temperature gradients within the HG region. At each site, a separate pit is excavated for cropped, CRP, and native land use conditions. Sites are in the same map units on similar geomorphic settings, even though the series may change based upon management. Samples collected from each management-site combination are returned to the either Lincoln or Fort Collins analyses. Soil-physical, -mineralogical, -micromorphological, and -chemical characterization will be done by the Lincoln laboratory The Fort Collins laboratory will be responsible for collection of data on above-ground biomass, plant-species characterization, and laboratory analyses for various C-pools (including: total-organic, identifiable plant-material, particulate organic-matter, mineral-associated, and microbial biomass-C). Isotopic analyses for $^{13}C/^{12}C$ ratios and ^{14}C dating will be done on selected samples to better assess issues related to C-sequestration processes and timing.
RESULTS: Sites have been sampled in CO, NE, and IA to obtain the West to East transect and in TX and MT to obtain a South to North transect. Samples were also collected in MO with some additional shallow sampling in CO. All samples have been returned to the respective laboratories and analyses are underway. Total soil organic C (to 2 m) increases along the precipitation gradient with average amounts of 92500, 108000, and 135000 kg/ha in CO, NE, and IA, respectively. The top 10 cm of the soil profiles were the most sensitive to land management. Organic C in the top 10 cm, as a % of the total profile C within each state increases moving from cropped to CRP to native sites.
FUTURE PLANS: Field collection of samples will be resumed this coming spring. The focus at that time will be upon completing our field sampling at sites in MN and ND.

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[1]NRCS, Lincoln, NE.

PUBLICATIONS:

PRUESSNER, E.G., R.F. FOLLETT, J.M. KIMBLE, and S.E. SAMSON. 1995. Soil properties and carbon storage within soil profiles of the historic grasslands of the USA - Part II. Agron. Abs. 87:285.

SAMSON, S.E., J.M. KIMBLE, R.F. FOLLETT, and E.G. PRUESSNER. 1995. Soil properties and carbon storage within soil profiles of the historic grasslands of the USA - Part I. Agron. Abs. 87:284.

Carbon Sequestration in No-till Management Systems at 3 Locations in Texas

Principle Scientists: Kenneth N. Potter H. Allen Torbert

Cooperating Scientists: John E. Morrison, Jr. Ordie R. Jones John E. Matocha Paul W. Unger

ARS GCRP: Res Area: Structure and Function; Prog. Elements: Biogeochemical Systems Objs: 2; Task: 3.

Cris Number: 6206-12000-002-00D 6206-61660-002-00D

Problem: Soil organic carbon (SOC) distribution is altered by residue management practices, but the effect on total carbon mass is not well understood, especially in warm regions. Only limited information is available regarding soil organic carbon (SOC) distribution and total amounts that occur in dryland cropping situations in Texas.

Approach: We used long-term research plots at 3 locations in Texas, ranging from the semiarid southern Great Plains at Bushland, Texas, to the warmer and wetter conditions at Temple and Corpus Christi, to determine crop rotation, tillage, and fertilizer effects on SOC distribution and mass. The effect of fallow in the crop rotation was also tested at the Bushland location. Potential N and C mineralization was measured at Temple.

Findings: No-till treatments resulted in significant differences in SOC distribution in the soil profile compared to stubblemulch tillage in four crop rotations at Bushland,with the largest differences occurring in continuous cropping systems. Organic carbon was concentrated in the surface seven cm of soil in the no-till system. Total SOC mass in the surface 20 cm was increased in the no-till system compared to the stubblemulch system in the continuous wheat and continuous sorghum systems, but was not significantly larger in wheat/fallow and wheat/sorghum/fallow cropping systems. No-till management with continuous crops sequestered carbon in comparison to stubblemulch management on the southern Great Plains. Fallow limits carbon accumulation.

Comparing continuous cropping systems at all 3 locations, no-tillage management resulted in increased SOC concentration and mass near the surface in comparison to more intensive tillage management (e.g. sweep, chisel plow, moldboard plow). The mass of SOC varied among locations depending on management, crop, soil, and climatic conditions. Fertilization had little effect on carbon sequestration at any site. The potential C and N mineralization of the Temple site indicated that intensively tilled soils had a greater propensity for C mineralization and that C accumulation in no-till may be of more recalcitrant forms of C.

Future Plans: Determination of management effects on soil organic carbon for a wide range of soils and climates.

Publications: See other side.

Potter, K.N., O.R. Jones. H.A. Torbert, and P.W. Unger. 1996. Crop rotation and tillage effects on organic carbon sequestration in the semiarid southern great plains. Soil Sci. (Submitted).

Potter, K.N., H.A. Torbert, O.R. Jones, J.E. Matocha, J.E. Morrison, Jr., and P.W. Unger. 1996. Distribution and amount of soil organic carbon in long-term management systems in Texas. Soil Tillage Res. (Submitted).

Reicosky, D.C., W. A. Dugas, and H.A. Torbert. 1996. Tillage-induced carbon dioxide loss from different cropping systems. Soil Tillage Res. (Accepted).

Torbert, H.A., K.N. Potter, and J.E. Morrison Jr. 1996. Tillage intensity and fertility level effects on nitrogen and carbon cycling in a vertisol. Commun. Soil Sci. Plant Anal. (Submitted).

USE OF CARBON-13 ISOTOPE CONTENTS OF GREAT PLAINS SOILS AND WHEAT-FALLOW CROPPING SYSTEMS TO DETERMINE SOIL ORGANIC MATTER POOL SIZES AND DYNAMICS

R. F. Follett - Co-investigators: E. A. Paul[1], S. Leavitt[2],
A. D. Halvorson[3], D. Lyon[4], and G. Peterson[5]
Research Area I, Program Element B, Objective 1, Task 3.

PROBLEM: The naturally occurring ^{13}C isotope has only recently been utilized as a tracer where plants with photosynthetic pathways have occurred in a time sequence in either managed or unmanaged agroecosystems. Sufficient published information and knowledge of native plant vegetation for the North American Great Plains now exists to begin to use $^{13}C/^{12}C$ isotope ratio data as a powerful tool for studying SOM dynamics. The current strong interest in soil organic matter (SOM) as a source-sink in global carbon (C) cycling between the atmosphere and agricultural soils now makes the use of ^{13}C an important tool for studying C sequestration in soils, especially if the data obtained are combined with that from carbon dating.
APPROACH: Archived soil samples, collected in 1947/49 from native grassland sites throughout the Great Plains of the USA, were obtained from their storage site at the Northern Great Plains Research Center in Mandan, ND. Data was also obtained for soils of the Canadian prairies. Soils sampling from Akron, CO and Sidney, NE included native grassland vs. long-term wheat-fallow cultivation. Visible plant material and inorganic C was removed and the total organic-C and the $^{13}C/^{12}C$ isotope ratio of the SOM determined by C/N analyzer and mass spectrometry. Historical yield records were obtained for both the Akron, CO and the Sidney, NE locations (both long-term experimental sites) for the purpose of estimating amounts and types of crop-residue C that had been returned to the soils at both locations.
RESULTS: The $^{13}C/^{12}C$ isotope ratio of native grassland, expressed as $\delta^{13}C$, ranged from -25.2 in the Canadian prairies to -14.9 at Dalhart, TX. This range is the result of historic mixtures of cool (C_3) and warm (C_4) season plant-species and the C-signature that their respective photosynthetic pathways have imparted to the SOM. At Akron, CO and Sidney, NE; the native grassland with an inherent C-signature that resulted from a historic mixture of mostly C_4 with some C_3 species was converted to wheat-fallow. Wheat is a C_3 species with a $\delta^{13}C$ of about -26. By isotopic ratio techniques and careful measurement of the total-organic soil-C, we have calculated the contribution of small-grain (wheat) residues to the SOM now present on these sites. Estimates of C accreted into the SOM pool from small-grain crops at Akron, is 18 to 21 kg plant-residue C/kg of C accreted into the soil organic-C pool. The corresponding value at Sidney is 10 kg plant residue C/kg soil organic-C. Cultivation initially depletes near surface soil-C with deeper soil-C becoming depleted with increasing time of cultivation.
FUTURE PLANS: This work will be submitted for publication and additional site studies are planned that will more thoroughly consider the effects of soil depth on soil-C.

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[1]Crop & Soil Sciences, MI State Univ., [2]Laboratory of Tree Ring Res., Univ. of AZ, [3]ARS, Mandan, ND,, and [4]Panhandle Res. and Ext. Ctr., Univ of NE. [5]Dept. of Soil and Crop Sci., CO State. Univ.

USE OF CARBON DATING FOR GREAT PLAINS SOILS TO DETERMINE SOIL ORGANIC MATTER POOL SIZES AND DYNAMICS

R. F. Follett - Co-investigators: E. A. Paul[1], S. Leavitt[2],
A. D. Halvorson[3], D. Lyon[4], and G. Peterson[5]
Research Area I, Program Element B, Objective 1, Task 3.

PROBLEM: Recent interest in soil organic matter (SOM) as a source-sink in global carbon (C) changes results from assessments that a major part of the overall radiative climate forcing in global change is attributed to atmospheric carbon dioxide, of which large quantities are cycled between the atmosphere and agricultural soils. SOM and the C it contains reflect long-term effects of vegetation, soil biota, climate, parent material, time, and the disturbances by human management on ecosystem functioning. Use of carbon-14 dating techniques to determine the longevity of C storage in SOM is an emerging science; especially when applied on a regional basis.

APPROACH: Archived soil samples, collected from sites in the Great Plains of the USA in 1947/49 were obtained from storage. Field samples were also collected from Akron, CO and Sidney, NE (native grassland vs. long-term cultivation). Additional samples and/or data were obtained for Sterling, CO and Maricopa, AZ in the USA and from Waldheim and Lethbridge in Sask, Canada. Soil samples were processed by removing recent plant material. Acid hydrolysis on 1- to 3-g of soil sample was by refluxing in 6N HCl for 18h to obtain a resistant SOM fraction (hydrolysis residue) that remained after soluble materials were separated. Carbon age was measured on both hydrolysis residue and the processed soil. Soil-C age, based upon ^{14}C activity, was determined on a tandem-accelerator mass spectrometer at the Univ. of AZ.

RESULTS: Latitude did not affect ^{14}C age; it strongly influenced SOM content. Cultivation resulted in lower C content and decreases in the percent modern C equivalent to an increase of 900 yr in ^{14}C age. The effect of depth was consistent and striking. The 10 to 20 cm depths were 1200 yr older than the 0 to 10 cm depth for both cultivated and native sites. The applicability of ^{14}C dating, in conjunction with acid hydrolysis, of the soils is demonstrated. The percent of nonhydrolyzable C and its mean residence time identifies the amount and turnover rate of the resistant soil C. This information is used in conjunction with data from extended mineralization studies to analytically determine the pools and fluxes of SOM. This approach provides information on soil pedogenesis and analytically establishes pool size and flux rates of the resistant soil organic C for modeling purposes. Resistant SOM fractions were observed to be so old that; although of great importance from a soil-structure and nutrient, water and pesticide absorption standpoint; likely, play only a small role in nutrient

FUTURE PLANS: This work will be submitted for publication and additional site studies are planned that will more thoroughly consider the effects of soil depth on the MRT of soil-C.

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[1] Crop & Soil Sciences, MI State Univ., [2]Laboratory of Tree Ring Res., Univ. of AZ, [3]ARS, Mandan, ND,, and [4]Panhandle Res. and Ext. Ctr., Univ of NE. [5]Dept. of Soil and Crop Sci., CO State. Univ.

PUBLICATIONS:

PAUL, E.A., W.R. HORWATH, D. HARRIS, R. FOLLETT, S. LEAVITT, B.A. KIMBALL and PREGITZER. 1995. Establishing the pool sizes and fluxes in CO_2 emissions from soil organic matter turnover. pp. 297-305 IN R. Lal, J. Kimble, E. Levine, and B.A. Stewart (eds.) Advances in Soil Science -- Soils and Global Change. CRC - Lewis Publishers. Boca Raton FL.

LEAVITT, S.W., R.F. FOLLETT, and E.A. PAUL. 1995. Estimation of slow and fast-cyling soil organic carbon pools from 6N HCl Hydrolysis. Proceedings of the 15th Int. Radiocarbon Conference. Glascow Scotland (August 1994). Journal of Radiocarbon: ^{14}C Dynamics of Soils 37(2):

Title: SOIL ORGANIC CARBON CHANGES AS AFFECTED BY TIME AND ROTATION INTENSITY ACROSS AN EVAPOTRANSPIRATION GRADIENT

Principle Scientists: L.A. Sherrod, G.A. Peterson, D.G Westfall, and G.S. McMaster

Cooperating Scientists:

ARS GCRP: Res. Areas: 1 ; Prog. Element: B ; Objs: 2 ; Tasks: 3.

CRIS Numbers: 5402-61660-005-00D

Problem: The practice of summer fallow within the Wheat-Fallow (WF) cropping system in the Central Great Plains is a costly practice environmentally. Research hasshown substantial losses of organic carbon (C) during the past 50-70 years of crop production. By implementing no-till management, conservation of soil moisture is increased enough to support more crops over time than traditional WF. More intensive cropping under no-till management causes an accumulation of crop residues on the soil surface which promotes microbial growth on and near the soil surface which promotes increases in C levels.

Approach: Three research sites in CO were established in 1985 across an ET and soil gradient (Catena). All sites had been under conventional WF production practices for over 50 years. Cropping systems managed by no-till practices were imposed across these catena's with two replications present and every phase of each cropping system rotation represented each year. These systems are Wheat-Fallow (WF), Wheat-Corn,Fallow (WCF), Wheat-Corn-Millet-Fallow (WCMF), and opportunity cropping (OPP). Continuous grass (CG) was also included as a comparison of the native prairie. Soils were sampled in 1986 in 3 depth increments of 0-2.5 cm, 2.5-5 cm, and 5-10 cm and each year from 1989 to present. All five cropping systems will be included in this study. This research will study changes in C and N over time as well as the differences between initial and final carbon levels.

Findings: Rotations with less fallow time are showing C increases. C levels are showing a positive response in the WCMF, OPP, and CG rotations in the 0-2.5 cm depth whereas WF and WCF are maintaining or showing a negative response. With the depths summed to 10 cm, cultivated systems maintained initial 1986 C levels with the exception of WCF. CG showed increases in C in all depths at all sites. The high ET site (lowest initial C), gained or maintained in all rotations except WF. The site (highest initial C), had the greatest losses.

Future Plans: Changes in soil organic carbon and in soil organic nitrogen will continue to be monitored. Residue quantity and quality will also be addressed as factors that relate to how fast these inputs are converted into the organic pool.

Publications:

Peterson, G.A., D.G. Westfall, and R.L. Kolberg. 1995. Fertilidad en trigo y otros .....de Suelos, Fertilizacion y Siembra Directa. III. Jornadas Regionales Symposium, September 1995. Sierra de la Ventana, Argentina.

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Title: Carbon Dioxide and Climate Change Effects on Crops and Trace Gas Exchange with the Atmosphere

Principal Scientists: L.H. Allen, Jr. and J.C.V. Vu

Cooperating Scientists: J.T. Baker, K.J. Boote, D. Pan, and N.B. Pickering

ARS GCRP CRIS Number: 6615-11000-004-00D Date: June 1996

Problem: Rising carbon dioxide and other greenhouse-effect gases will change crop productivity through (a) photosynthetic acclimation to the CO_2 fertilization effect and (b) other plant growth responses to anticipated global warming and changes in precipitation. Research is required to quantify these productivity changes, and to identify management and genetic adaptations to ameliorate potential negative impacts. Moreover, agriculture also contributes to emissions of greenhouse-effect gases (e.g., methane, CO_2, and nitrous oxide). Flooded rice culture contributes about 15 to 20% of the global methane emissions. Research is needed on (a) the effect of increased CO_2 and temperature on methane effluxes and (b) water management practices that would decrease emissions while sustaining crop productivity.

Approach: Experiments are conducted in controlled-environment, Soil-Plant-Atmosphere Research (SPAR) chambers and in temperature-gradient greenhouses. SPAR chambers control CO_2 concentration, air temperature, dewpoint temperature, and soil water conditions in natural sunlight with large rooting volume. Temperature-gradient greenhouses provide 4 segments with differences maintained at 1.5°C steps above ambient. Temperature x CO_2 treatments are provided by paired CO_2-enriched and ambient-CO_2 greenhouses.

Findings: Rice. Experiments in SPAR chambers showed that methane emissions in paddy-culture were greatly increased by elevated CO_2. However, watertable drawdown to the point of drought during panicle initiation drastically reduced methane effluxes without causing a yield reduction, regardless of CO_2 exposure level. Drought during anthesis did cause a yield reduction. We conclude that carefully managed watertable drawdowns should result in sharp decreases in methane emissions with no loss of productivity. Forages. Experiments with a C-4 grass (Bahiagrass) and a C-3 forage legume (Rhizoma peanut) in temperature-gradient greenhouses showed little response of photosynthesis and growth, partitioning, and carbon sequestration across a range of 4.5°C above ambient. Doubled CO_2 (350 to 700 μmol mol^{-1}) increased growth of rhizoma peanut and bahiagrass about 30% and 10%, respectively.

Future Plans: (1) Conduct studies on photosynthetic acclimation of rice leaves and canopies to elevated CO_2 and N fertilization. The objectives are to determine the effect of photoassimilate sources and sinks on leaf rubisco limitations and on RuBP regeneration capacity under a relatively low N and very high N fertility regime. The N factor must be considered because our early studies on soybean (N-fixing legume) showed no downregulation of photosynthesis or decrease in rubisco protein, whereas rice showed both downregulation and decrease of rubisco at a common level of N fertilization. (2) Continue study of CO_2 and temperature effects on photosynthesis, growth, and plant and soil carbon sequestration of 2 forages.

Publications: (July 1995-June 1996).

Allen, L.H., Jr., J.T. Baker, S.L. Albrecht, K.J. Boote, D. Pan, and J.C.V. Vu. 1995. Carbon dioxide and temperature effects on rice. pp. 258-277. In S. Peng, K.T. Ingram, H-U. Neue, and L.H. Ziska (ed.) Climate Change and Rice. Springer-Verlag Berlin Heidelberg.

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Report of Progress

Trace Gas Emissions from Agricultural Cropping Systems:
Soil, Plant, and Animal Production
(Methane Emissions from Swine Lagoons and
Nitrous Oxide Emissions after Effluent Application)

Ron R. Sharpe and Lowry A. Harper

ARS GCRP: Res. Areas: 1; Prog. Elements: B; Objs: 3; Tasks: 1,8.
CRIS Numbers: 6612-13610-001-00D
6612-12000-008-00D

Problem: There has been substantial increases in the concentrations of greenhouse gases (CO_2, CH_4, and N_2O) associated with agricultural practices. Both CH_4 and N_2O emissions can be influenced by livestock production and animal waste disposal methods. Methane can be produced directly by ruminant animals and by decomposition of animal waste products. Seventy-five percent of swine production systems in North America use anaerobic or liquid/slurry systems for waste holding or disposal and the EPA has estimated that 788,000 metric tons of CH_4 are produced each year from anaerobic swine lagoons. This estimate is based on maximum CH_4 producing capacity, CH_4 conversion factors, and climate adjustment factors because there are few direct measurements of CH_4 fluxes from lagoons. Emission of N_2O from cultivated land and perhaps from fossil fuel use are the two primary contributions by agriculture to global N_2O emissions. Application of animal waste effluent to soils may increase denitrification and N_2O emissions. Effluent contains both N (NO_3 and NH_4) and soluble C which often limit N_2O production. Irrigation with effluent also decreases soil oxygen and thus may result in large pulses of N_2O emissions from soils. The purpose of these studies is to use techniques to evaluate radiatively active trace gases without disturbing the plant, animal, or management system being measured.

APPROACH: Micrometeorological techniques (specifically the momentum balance technique) was used for measurement of trace gases over the lagoon and in the field. In the lagoon study, meteorological and gas-sampling equipment were constructed on a pontoon barge which was floated to the center of the lagoon. Adjustable legs were extended to the solid bottom and the barg was sunk to just below the waterline to reduce aerodynamic resistance by the structure. Trace gas concentration measurement included tunable diode laser spectroscopy (CH_4 and N_2O), infrared gas analysis (CO_2), and gas-washing techniques (NH_3). Corollary measurements included climatic (windspeed, air and water temperature, radiation) and lagoon (nutrient content; pH; methane potential; dissolved oxygen, methane, nitrous oxide, and carbon dioxide; and sludge depth) measurements. Where lagoon effluent was land-applied, soil and plant measurements were made.

FINDINGS: Methane emission measurements from the swine lagoon were made in December 1994, February 1996, and April 1996. Average CH_4 flux rates were 46 and 37 kg/ha/day during December 1994 and February 1996, respectively. Most of the variability in CH_4 emissions

(r^2=0.74) was explained by water temperature and windspeed. Final CH_4 fluxes during April 1996 have not been calculated but a comparison of the changes in atmospheric CH_4 concentrations with height over the lagoon between the spring period and winter periods indicate that the spring fluxes will be greater. Nitrous oxide emissions from soil were low (0.01 kg/ha/day) prior to effluent applications. After effluent application, N_2O fluxes increased from about 0.19 kg/ha/day after the first application to greater than 0.42 kg/ha/day after the third application.

FUTURE PLANS:

1. Measure CH_4 fluxes from the primary lagoon during August (warmest season).
2. Measure CH_4, N_2O, and NH_3 from grazing cattle under field conditions using the micrometeorological mass difference technique.
3. Measure CH_4, N_2O, and CO_2 fluxes from a secondary lagoon.
4. Nitrogen mass balance including feed input, animal nutrient retention, and ammonia loss from the rearing barns.
5. Lagoon ammonia emissions to the atmosphere (about 18,000 kg ha^{-1} $year^{-1}$) must be absorbed into surrounding natural ecosystems. Absorption into surrounding grass/pine-tree ecosystems will be measured using new laser spectrometry for gas analysis.
6. A carbon balance will be made on the lagoon system to attempt to evaluate methods by which methane emissions may be reduced.

PUBLICATIONS:

1. Harper, L.A., and R.R. Sharpe. 1995. Nitrogen dynamics in irrigated corn: Soil-plant nitrogen and atmospheric ammonia transport. Agron. J. 87:669-675.
2. Sharpe, R.R. and L.A. Harper. 1995. Soil, plant and atmospheric conditions as they relate to ammonia volatilization. Fert. Res. 42:149-158.
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8. Dias, G.T., G.W. Thurtell, C. Wagner-Riddle, and L.A. Harper. 1996. Measuring ammonia fluxes from soil with a laser- based trace gas analyzer. Proc. Amer. Soc. Agric. Engr., Kansas City, Mo. (abstract)

Report of Progress

Trace Gas Emissions from Agricultural Cropping Systems: Soil, Plant, and Animal Production (Ammonia Emissions from Swine Lagoons)

Lowry A. Harper and Ron R. Sharpe

ARS GCRP: Res. Areas: 1; Prog. Elements: B; Objs: 3; Tasks: 1,8.
CRIS Numbers: 6612-13610-001-00D
6612-12000-008-00D

Problem: Seventy-five percent of swine production systems in North America use anaerobic or liquid/slurry systems for waste holding or disposal. Because of increased production efficiency and economics and a better industry support system, production is concentrated into relatively small regions causing potential problems of waste disposal and natural (ecological) system absorption of excess nutrient byproducts to the surface water, groundwater, and to the atmosphere. In order to evaluate the effect of animal concentrations on the regional soil, surface and ground waters, and atmospheric environments, accurate emission factors are needed by planning and regulatory agencies. Emission factors, developed mainly in northern Europe, are variable and questionable for use in the subtropical to temperate regions of the United states. Measurements made in the United States have also been variable ranging from zero to over 500 kg NH_3 animal^{-1} y^{-1}. Emission factors for methane and nitrous oxide are equally as variable because of the use of inappropriate methodology or inadequate sensitivity of analytical equipment. The purpose of these studies is to use techniques to evaluate radiatively active trace and other gases without disturbing the plant, animal, or management system being measured.

APPROACH: Micrometeorological techniques for non-interference measurements include gradient diffusion, micrometeorological mass difference, and isotopes. For measurement of trace gases over large lagoons, the gradient diffusion (specifically the momentum balance) technique was determined most appropriate but new equipment was designed for instrumentation and sampling. Meteorological and gas-sampling equipment were constructed on a pontoon barge which was floated to the center of the lagoon. Adjustable legs were extended to the solid bottom and the barg was sunk to just below the water surface to eliminate to reduce aerodynamic resistance by the structure. Trace gas concentration measurement included tunable diode laser spectroscopy, infrared gas analysis, and gas-washing techniques. Aerosols were measured using microfilters. Corollary measurements included climatic (windspeed, air and water temperature, radiation) and lagoon (nutrient content; pH; methane potential; dissolved oxygen, methane, nitrous oxide, and carbon dioxide; and sludge depth) measurements. Where lagoon effluent was land-applied, soil and plant measurements were made.

FINDINGS: Ammonia emissions varied diurnally and seasonally, from low emissions during winter and low windspeeds and high emissions during summer and high windspeeds. The highest correlation was with nutrient concentration followed by water temperature. Most of the variability in emissions (r^2=0.94) was explained by water ammonium concentration, temperature,

pH, and windspeed. Nutrient loading of the lagoon system was measured which showed the largest percentage of nutrients accumulated in the first of four successive lagoons. Mobile ions which were non volatile (potassium, sodium) were constant in concentration throughout the four lagoons in both the effluent and in the sludge layer. Immobile ions (phosphorous, organic nitrogen, calcium, sulfur, magnesium, zinc, iron, manganese, copper) concentrated primarily in the sludge layer of the first lagoon (enrichments in the first lagoon ranged from five to a thousand [zinc] times higher than in the secondary lagoons). Nitrogen decreased in concentration from about 1400 ppm in the sludge layer of the first lagoon down to less than 50 ppm in the fourth lagoon. Measurements were made for a partial nitrogen mass balance, and nitrogen removal pathways included ammonia emissions (32%), retention in the sludge layers (12%), seepage (13%), and irrigation onto cropland (2%). Unaccounted for nitrogen was 40% of the input. Speculated other losses included denitrification in the third and fourth lagoons (to nitrogen gas--no nitrous oxide gas was measured) and ammonium aerosols. Mass balance for all other nutrients were evaluated.

FUTURE PLANS:

1. There is no accurate estimate of methane, nitrous oxide, and ammonia emissions from dung under pasture conditions. Using the micrometeorological mass difference technique, measure radiatively-active and other trace gases from grazing cattle.
2. Measure methane fluxes from a swine lagoon during the warm (summer) season.
3. Measure radiatively-active and other trace gases in secondary waste lagoons.
4. Measure ammonia emissions and lagoon-nitrate denitrification in secondary waste lagoons.
5. Nitrogen mass balance in animal rearing barns including feed input, animal nutrient retention, and ammonia loss.
6. Lagoon ammonia emissions to the atmosphere (about 18,000 kg ha^{-1} $year^{-1}$) must be absorbed into surrounding natural ecosystems. Absorption into surrounding grass/pine-tree ecosystems will be measured using flux-gradient techniques and new laser spectrometry for gas analysis.
7. A carbon balance will be made on the lagoon system to attempt to evaluate methods by which methane emissions may be reduced.

PUBLICATIONS:

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Simulation of Regional Soil Nitrogen Gas Fluxes Using NLEAP

Principal Scientists: M.J. Shaffer and C. Xu
Cooperating Scientists: M.K. Brodahl, G. Hutchinson, and R.F. Follett

ARS GCRP: Res. Areas: I; Prog Elements: AB; Objs: 3,3; Tasks: 3,4

CRIS Number: 5402-61660-004-00D

Problem: The need exists for an effective and efficient means of simulating emissions of nitrogen gases from soils across broad geographical areas as a function of soil properties, climate and management inputs. The NLEAP model is being modified to include nitrogen greenhouse gas components (N_2O and NO_x).

Approach: This is a simulation modeling project with some field and laboratory work required to fill critical knowledge gaps and provide specific model validation data to calibrate and test the NLEAP model for soil gaseous N losses under selected agricultural conditions.

Findings: We modified the nitrification and denitrification submodels of NLEAP to simulate daily N_2O emission rates. During nitrification, the amount of N_2O emitted correlates with the amount of nitrifiable N in soils. We considered ammonium as the direct factor controlling N_2O emissions under aerobic soil conditions as a function of temperature and water content. In the denitrification submodel, the process was driven by a term for rainfall and irrigation events, and by a second term for periods between events. Both terms are a function of several driving variables. To test the response of N_2O emission to variations of relevant parameters, we simulated a clay loam soil, under fertilized and unfertilized conditions in 1995. Results indicated that temperature, rainfall events, soil physical and chemical properties, fertilizer applications, and crop varieties are all important factors which govern N_2O emission processes in soils. The percentage of the N_2O emitted relative to the total nitrogen amount derived from the fertilizer was about 1 percent. The trends and magnitudes of simulated N_2O losses using the modified NLEAP model were consistent with results obtained from local field experiments and from the literature, Mosier et al. (1982). A separate laboratory experiment involving N_2O emissions revealed that N_2O gas was produced from the soil profile from 0 to 60 cm. The late-time negative N_2O emission rate indicated that this soil may have a potential for N_2O absorption.

Future Plans: Collect field and laboratory data on soil gaseous N losses under selected cropping, management and soil conditions to test and validate the modified NLEAP model, and use this information to continue development of NLEAP as an effective tool for use by the NRCS. Demonstrate the utility of using the NLEAP model in conjunction with a GIS to estimate soil emissions of N_2, N_2O, and NO_x gases across broad landscape and regions.

Publications:

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Shaffer, M.J., B.K. Wylie, and M.D. Hall. 1995. Identification and mitigation of nitrate leaching hot spots using NLEAP-GIS technology. Journal of Contaminant Hydrology 20:253-263.

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USING FIELD FLUX MEASUREMENTS AND LABORATORY STUDIES TO DEVELOP PROCESS BASED GAS FLUX MODELS FOR N_2O AND N_2

A.R. Mosier: Coinvestigators W.J. Parton, D.W. Valentine, D.S. Ojima, and A. Kulmula

Project Number: 5402-11000-004-05S

PROBLEM: Since it is not possible to measure gas fluxes in all soils at all times it is necessary to develop simulation models which accurately describe trace gas fluxes from a wide variety of soils and climates. Such models are needed to assess regional fluxes and assess the impact of changes in climate and land use on fluxes of trace gases.

APPROACH: Using the information collected during the past five years, from a wide variety of grassland and cropland research sites and from laboratory studies, we have developed a process based model which describe the emission of N_2O and N_2 from the soil to the atmosphere.

RESULTS: A general model was developed to simulate N_2 and N_2O gas fluxes from nitrification and denitrification using laboratory denitrification gas flux data and field observed N_2O gas fluxes from different sites. The model simulates nitrification N_2O gas fluxes as a function of soil texture, soil NH_4^+, soil water content, soil N turnover rate, soil pH and soil temperature. Model results and observed data suggest that nitrification N_2O gas fluxes are proportional to soil N turnover and that soil NH_4^+ levels only impact N_2O gas fluxes with high level of soil NH_4^+ (> 3 ug /g). Total denitrification (N_2 plus N_2O) gas fluxes are simulated as a function of soil respiration rates, soil NO_3^-, soil water content and soil texture. N_2:N_2O ratio is a function of soil water content, soil NO_3^- and soil respiration rates. The denitrification model was developed using laboratory data where soil water content, soil NO_3^-, and soil C availability were varied using a full factorial design. Comparison of the model results with observed field data for the denitrification submodel shows that the model simulated N_2 and N_2O gas fluxes for different soils well with r^2 equal to 0.62, and 0.75, respectively. Comparison of simulated model results with field N_2O data for several validation sites shows that the model results compare will with the observed data, r^2 =0.62. The major discrepancy is that winter denitrification events, which are important in the annual gas flux picture, were poorly simulated by the model. The model results show that approximately 14% of the N_2O fluxes for a shortgrass steppe are a result of denitrification and that this percentage ranged from 0 to 59% for different sites and years. The model results also show that soil respiration and soil texture alter the impact of soil water content on N_2 and N_2O gas fluxes from nitrification and denitrification.

FUTURE PLANS: Further refinement of these models, as a result of further laboratory, for denitrification, and field studies, and linkage to the CENTURY model will continue. Once the trace gas flux module is linked with CENTURY a set of model comparisons using first the DNDC model will be conducted.

Collaborators are from the Natural Resource Ecology Laboratory , Colorado State University and the Agricultural Research Center of Finland

NO, N_2O, AND CH_4 EXCHANGE DURING N TRANSFORMATIONS IN SOIL

G.L. Hutchinson - Co-Investigators: J.W. Doran[1], M.F. Vigil[2]

CRIS: 5402-11000-004-00D

PROBLEM: NO, N_2O, and CH_4 are radiatively, chemically, and ecologically important trace atmospheric constituents. Microbial processes in soil are a major source of the NO and N_2O and both a source and sink for CH_4, so it is essential to understand exchange of these gases across the soil-atmosphere boundary and, if needed, to develop mitigation technologies. Short-term exchange rates of the three gases have recently been measured from several ecosystem types under a variety of soil and climatic conditions around the world, but longer-term studies that yield tenable estimates of seasonal-to-interannual exchange at a particular site are conspicuously absent from the literature. Assessing the contribution of the net soil source of each gas to its global atmospheric budget is further confounded by immense temporal and spatial variability in the exchange rates and by the apparent existence of multiple biotic and abiotic soil sources and sinks of the gases, each of which is subject to a different set of controllers.

APPROACH: Our overall goal is to capture field-measured exchange rates of the gases in terms of their basic physical, chemical, and biological controllers. Dependence of the fluxes on these controllers will be characterized in controlled laboratory soil incubation studies and then described using simulation models parameterized by variables observable across different scales.

RESULTS: We developed the structure of a process-based simulation model for describing soil-atmosphere NO and N_2O exchange and made preliminary attempts to parameterize the model using data collected from the CRP plots at the Central Great Plains Research Station and from native grassland at the Central Plains Experimental Range. The latter represent continuing year-around measurements that suggest NO emission may represent the principal control on long-term grassland N balance and productivity. In a separate study at nearby grassland sites, we found that NO emission was greater from sandy clay loam than clay sites and from C_4 compared to C_3 plant communities. In addition, we have nearly completed laboratory evaluation of the procedure (described in last year's report) that was proposed for separating nitrifier- from denitrifier-based NO and N_2O exchange in the field, and we designed and tested a new Cr_2O_3 converter for oxidizing NO to NO_2 in our luminol-based field instrument for real-time NO detection.

FUTURE PLANS: Additional field and laboratory experiments are planned to (1) improve the model's scheme for describing the dependence of NO and N_2O exchange on soil N availability, (2) develop a more effective method of including the event-driven NO and N_2O pulses described in a separate report, and (3) continue testing of the above-mentioned procedure for weighting nitrification and denitrification modules of the simulation model. Also, we will test our new Cr_2O_3 converter in a newly released model of the same instrument before publishing its description.

[1]USDA-ARS, Lincoln, Nebraska; [2]USDA-ARS, Akron, Colorado.

PERFORMANCE OF CHAMBERS FOR MEASURING TRACE GAS EXCHANGE

G.L. Hutchinson - Co-Investigators: G.P. Livingston[1], R.W. Healy[2], R.G. Striegl[2], H.K. Iyer[3]

CRIS: 5402-11000-004-00D

PROBLEM: Chambers play a critical role in research concerning surface-atmosphere trace gas exchange, so understanding their performance, accuracy, and limitations is essential to properly interpret published trace gas budgets, to develop and validate trace gas exchange models, and to conduct experimental studies of trace gas exchange processes. Deployment of either a steady-state or non-steady-state chamber inherently perturbs its underlying vertical and horizontal soil gas concentration gradients, thereby altering the surface-atmosphere gas flux that the chamber was intended to measure. Failure to understand and account for that perturbation results in the potential for significant error in estimating the true trace gas flux.

APPROACH: We are using a numerical gas diffusion model to examine steady-state and non-steady-state chamber feedback processes as a function of atmospheric interfacial layer depth, chamber headspace mixing, soil transport properties, and trace gas source/sink characteristics. It differs from other models used to investigate chamber performance in that it is 3-dimensional, uses a shorter time step, and specifically includes the chamber headspace in the simulated domain. We are also developing a nonlinear regression approach to trace gas flux estimation from non-steady-state chamber concentration data that employs a recently derived analytical solution of the 1-dimensional time-dependent gas diffusion equation.

RESULTS: The simulations indicated that performance of both steady-state and non-steady-state chambers was (1) weakly dependent on pre-deployment atmospheric interfacial layer depth, (2) strongly dependent on the intensity of headspace mixing, (3) poorest when soil transport properties supported rapid gas diffusion, (4) independent of the magnitude, distribution, or kinetics of trace gas sources, and (5) better for measuring trace gas sources than sinks in soil. A chamber-induced change in air mixing processes operating near the soil surface caused either rapid enhancement or rapid suppression of the assumed pre-deployment steady-state gas exchange rate. This initial perturbation was large compared to changes that followed, and it occurred far too rapidly to be captured by conventional chamber sampling techniques. Finally, we completed SAS simulations designed to determine the sensitivity of our proposed flux estimation method to analytical precision and to the number and timing of chamber concentration observations.

FUTURE PLANS: Following publication of these results (one manuscript accepted, one submitted, one in author review, and one in preparation), we plan laboratory studies (with some field backup) to confirm and extend the simulation results.

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EVENT-DRIVEN PULSES OF CO_2, NO, AND N_2O EMISSIONS FROM SOIL

G.L. Hutchinson - Co-Investigator: D.C. Reicosky[1]

CRIS: 5402-11000-004-00D

PROBLEM: A large pulse of CO_2, NO, and N_2O evolution often immediately follows wetting of very dry soil. The pulse is too large to be explained by water's well-defined effects on transport in soil, and its cause remains unclear. Similar pulses sometimes occur following rapid warming of soil previously exposed to near-freezing or subfreezing temperatures, following tillage of partially compacted soil, and possibly following sudden removal of other environmental limitations on microbial growth and metabolism. Emission rates during such an event may be up to 1000-fold higher than rates preceding or following the pulse, so the quantity of soil C or N lost during its brief duration may exceed the total amount emitted during the much longer period before the soil becomes predisposed to support another emissions pulse in response to the next perturbation.

APPROACH: Both experimental and modeling approaches are being used to examine the relative contributions of biological vs. physical/chemical mechanisms to each emission pulse as a function of the gas species and the pulse driver. A separate combination of field measurements and controlled laboratory soil incubation studies is designed to test the hypothesis that the biological contribution often results from decoupling consecutive reactions mediated by separate microorganisms with different sensitivities to the offending environmental limitation.

RESULTS: The pulse of NO and N_2O (but not CO_2) that followed wetting very dry soil was inhibited by nitrapyrin but not by chlorate, which are selective inhibitors of ammonium-oxidizing and nitrite-oxidizing bacteria, respectively. Denitrifying bacteria did not appear to be involved in pulse generation under the aerobic experimental conditions. Additional pulses occurred in response to subsequent wetting events only when desiccation first reduced evolution of all three gases to near zero. Pulses of the three gases that occurred in response to simulated tillage (hand mixing) in laboratory studies were not predictably related to either the intensity of disturbance or the elapsed time since the last physical disturbance, suggesting that we have not yet identified the antecedent condition that predisposes soil to support such a pulse. Preliminary studies of temperature-induced pulses have been even less predictable.

FUTURE PLANS: We will continue using selective microbial inhibitors and independent manipulation of the concentrations and transport rates of gas-phase and solution-phase reactants and products of microbial C and N transformations in soil to characterize the contributions of these and other processes to the pulse of CO_2, NO, and N_2O evolution following temperature, wetting, and physical disturbances in controlled laboratory soil incubation experiments. As time permits, and the need arises, laboratory findings will be tested in the field. Modeling studies will be used as an aid to interpreting the findings of both field and laboratory experiments.

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Publications

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SOIL-ATMOSPHERE EXCHANGE OF CH_4, N_2O, CO_2 AND NO IN WESTERN PUERTO RICO: EFFECT OF N-FERTILIZATION AND LIMING OF AN ACIDIFIED OXISOL

A.R. Mosier and J.A. Delgado: Collaborator M. Keller

Project Number: 5402-11000-004-00D

PROBLEM: The conversion of native tropical systems into agricultural uses is considered a major factor in the resent upsurge in increases in atmospheric N_2O concentration. The systems that had been studies were generally those from recent conversion. little is known about tropical systems that have been converted from forest to intensive agriculture which then were returned to relatively stable grasslands that are used for forage production. There is little information available to consider the impact of liming acid soils and N-fertilization on atmospheric trace gas constituents.

APPROACH: In 1987 plots within the ARS Isabela research station in western Puerto Rico were experimentally acidified to about pH 4 from a normal pH of 5.5-6. Plots were returned to grass and were undisturbed for several years. In 1993 we set up plots within the acidified area to determine the effect of lowed pH (pH remained at about 4 in 1993) on trace gas fluxes. In October 1994 a set of plots were limed to achieve pH 5.5 to 6 while other plots received no lime. In May, 1995 we conducted a study within both limed and unlimed plots to determine the effect of adding either nitrite or ammonium plus nitrification inhibitors DCD or acetylene on NO, N_2O and CH_4 flux within microplots established within the lime/unlimed main plots.

RESULTS: On the short term (2-24 hr) NO emissions were not altered by liming while N_2O emissions were significantly lower in the unlimed soil. In all cases the NO emissions were 2.5 to 10 times larger than N_2O in the relatively dry (30-40% WFPS) soil. Both DCD and acetylene decreased both NO and N_2O emissions in the limed soil. In the unlimed soil acetylene inhibited both NO and N_2O emission but DCD did not. DCD either blocks a part of the nitrification pathway that acetylene does not or possibly heterotrophic nitrifiers were responsible for nitrification in the acidified oxisol. Methane uptake was not altered by liming the acidified oxisol where it is typically 4-5 times less than the pH 6 oxisol soil. In the unlimed soil neither ammonium addition nor ammonium + DCD or acetylene affected methane uptake 24-hr after application. In the limed soil both DCD and acetylene decreased CH_4 uptake, suggesting that CH_4 oxidation may be mediated by different organisms or pathways in limed and unlimed soils.

FUTURE PLANS: Studies at the sites in Puerto Rico were terminated at the end of September, 1995. Manuscripts from the data collected are to be written and the data set are being included in the U.S. Trace Gas Network data set and will be used in a regional modeling effort.

Collaborator: Michael Keller, USDA/Forest Service, Rio Piedras, Puerto Rico.

NITROGEN BIOGEOCHEMISTRY AND N GAS EMISSIONS IN THE SHORTGRASS STEPPE

A.R. Mosier: Coinvestigators R. Martin, W.J. Parton, D.S. Ojima, D.W. Valentine

Project Number: 5402-11000-004-00D

PROBLEM: Recent studies in grasslands have found that gaseous N losses may be a key regulator of biogeochemistry of these ecosystems. Limited results from our studies suggest that rates of N gas loss from grasslands may be the principal control on long-term grassland N balance and productivity. Along with its role in regulating primary productivity, the N cycle of terrestrial ecosystems interacts with atmospheric trace gas chemistry in important ways. Our understanding of the dynamics and magnitudes of N gas fluxes relative to the magnitude of process which regulate N turnover is inadequate to permit prediction of the long term impact of changes in land management and climate on the ecosystem.

APPROACH: From the 24 sites where trace gas studies have been conducted at the Central Plains Experimental Range six were selected with differing textures, landscape positions and management. The soil-atmosphere exchange of NO, N_2O, CH_4 and CO_2 were measured periodically, year-round throughout 1995 to assess the impact of site variables and management on annual fluxes of these gases.

RESULTS: N-fertilization of the shortgrass steppe (SGS) with either low level fertilization to increase forage production or high amounts of N in cattle urine deposition increase both NO and N_2O emissions from fertilized soils for many years after fertilization. At sites that were fertilized with about 20 kg ammonium nitrate-N ha^{-1} yr^{-1} from 1976 until 1989 NO emissions averaged 29 ug N $m^{-2}hr^{-1}$ compared to 18 ug N $m^{-2}hr^{-1}$ in native sites. During the same period N_2O flux averaged 4.3 and 2.3 ug N $m^{-2}hr^{-1}$ in fertilized and native grassland, respectively. At another set of sites where about 500 kg N ha-1 of urea-N was applied in 1982 to simulate cattle urine deposition, NO flux averaged 30, compared to 12 ug N $m^{-2}hr^{-1}$ in native plots. Over the same period N_2O flux averaged 3.7 and 1.3 ug N $m^{-2}hr^{-1}$ in fertilized and native plots, respectively. When the effect of enhanced NO emissions with precipitation events is included in emission estimates NO emissions in native pastures constitute approximately 50% and N_2O about 5% of N input into the SGS through atmospheric deposition. Long term N-retention studies at the high N fertilization site suggest that although the N cycle is relatively tight and N losses are low the continual emissions of N-gases regulate N retention in the system.

FUTURE PLANS: Studies to further understand N biogeochemistry in the grassland as it relates to system productivity and NO, N_2O, CO_2 and CH_4 flux will continue.

Coinvestigators are in the Natural Resource Ecology Laboratory, Colorado State University

Title: Regional Rangeland Grasshopper Outbreaks-Testing the Resource Limitation Hypothesis
Principal Scientists: W. P. Kemp
Cooperating Scientists: Brian Dennis, Tony Joern
ARS GCRP: Res. Areas: I & V ; Prog. Elements: I-C, I-D, & V-B; Objs: I-C-1, I-C-4, I-D-1, & V-B-1; Tasks: I-D-1-1 & V-B-1-1.
CRIS Numbers: 0500-00026-016-00D & 5401-11000-004-00D

Problem: Rangeland grasshopper outbreaks in the Northern Great Plains can develop over short time periods, exhibit extreme densities, can cover large areas of grasslands and crops (thousands and tens of thousands of hectares), and can cause complete destruction of regional-scale forage and crop production in a given year. Our results strongly suggest that we should focus our attention on connections between regional grassland resource fluctuations, including the link to larger scale meteorological and climatological circulation processes, and the development and collapse of regional rangeland grasshopper outbreaks.

Approach: We are: 1) utilizing NOAA Advanced Very High Resolution Radiometer (AVHRR) data and Normalized Difference Vegetation Indices (NDVI) for describing regional forage production in space and time from 1988 through 1996; and 2) developing "spatiotemporally sensitive environmental covariates" to improve stochastic forecasting methods that we have developed for rangeland grasshoppers.

Findings: We have focused on: 1) acquiring AVHRR/NDVI data for North America from the EROS Data Center; 2) obtaining additional storage capacity for our SUN workstation; and 3) recruiting and training two graduate assistants. We have completed a validation test of a method for stratified sampling of NDVI coverages which provides statistically valid subsamples for further analyses (at a greatly reduced cost in terms of space and processing time) and have completed an analysis of the spatial variability of grassland NDVI values across the ecoregions and grassland cover types throughout the Northern Great Plains (1988-1993).

Future Plans: We will proceed: 1) with the modification of our stochastic grasshopper density forecasting model to accept an environmental covariate and reparameterize the model based on current density, ecoregion, and regional forage production; and 2) with the development of a series of graphical and GIS products that describe the relationship between regional grasshopper outbreak development and ecoregion, forage production, and grasshopper density. Our modeling activities will contribute to regional- to global-scale terrestrial models that are designed to use remotely sensed data to quantify various states (or likelihoods) of terrestrial systems.

Publications:

Cigliano, M. M., W. P. Kemp, and T. M. Kalaris. 1995. Spatiotemporal characteristics of rangeland grasshopper (Orthoptera: Acrididae) regional outbreaks in Montana. Journal of Orthoptera Research 4:111-126.

Dennis, B., W. P. Kemp, and M. L. Taper. 1996. Joint density dependence. Ecology. In press.

A suite of crop models with similar characteristics that respond mechanistically to carbon dioxide concentration, and other environmental variables.

Principal Scientists: Basil Acock, Hal Lemon and Vangimalla R. Reddy

Cooperating Scientist: Yakov A. Pachepsky

ARS GCRP: Res. Area: I; Prog. Element: C; Obj.: 1; Tasks: 1, 2 and 3.

CRIS Number: 1270-66000-013-00D

Problem:
A modular structure suitable for modeling all crop species would facilitate comparison of various hypotheses about plant growth, allow other specialists to contribute their ideas, and extend the life of the model indefinitely because it could be easily updated as new knowledge became available. For making predictions about crop responses to climate change, a suite of models with similar characteristics and the same structure is highly desirable. Such a suite would enable us to focus on crop differences instead of model differences.

Approach:
Examine object-oriented programming languages for their potential to support a modular structure for crop models. Define possible modular structures and obtain critical comment. Implement the chosen structure in the chosen language as a shell, i.e. with "hollow" modules that return appropriate but not necessarily correct values. Fill in the modules with code or algorithms from existing models. Validate the models and use them for predicting crop responses to climate change.

Findings:
An object-oriented, modular generic structure was developed and implemented as a shell in both C++ and Fortran 90. C++ was chosen as the more versatile language for the suite of models. A cotton model is being created from the shell in collaboration with the Crop Simulation Research Unit, Mississippi Sttae University.

Future Plans:
Work on a wheat model is planned to start in August, 1996.

Publications:
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Reynolds, J. F., Kemp, P. R., Acock, B., Chen, J-L. and Moorhead, D. L. Progress, limitations, and challenges in modeling the effects of elevated CO2 on plants and ecosystems. pp. 347-380, 1996. In Koch, G. W. and Mooney, H. A. (eds.)Carbon Dioxide and Terrestrial Ecosystems , Academic Press, San Diego, CA. (Book of conference proceedings)
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A Two-Dimensional Model of Soil Physical, Chemical and Biological Processes.

Principal Scientist: Dennis Timlin

Cooperating Scientist: Yakov A. Pachepsky

ARS GCRP: Res. Area: I; Prog. Element: C; Obj.: 1; Task: 4.

CRIS Number: 1270-66000-013-00D

Problem:
Many crops are grown in rows, and many field operations result in two-dimensional variation in the soil environment at right angles to the row. Crop responses to climate change can only be fully understood and modeled if we account for fertilizer and irrigation water placement, root growth and surface topography, and the effect these have on water and nutrient availability.

Approach:
Develop a two-dimensional soil and root model using a modular structure for versatility. Design an interface to crop models to permit rapid coupling to these models. Incorporate existing code to the extent possible. Write new code as needed to describe the most important soil processes. Validate the model using published data. Couple the soil and root model to various crop models and validate the combined model. Use the combined models to predict possible crop responses to climate change.

Findings:
The two-dimensional model of soil and root processes, 2DSOIL has been validated with many datasets and several crop models. Version 3 of the documentation of 2DSOIL has been released. A graphic user interface has been developed to facilitate generation of the input files needed by 2DSOIL. There is good agreement between measured and simulated soil water contents, except where 2DSOIL has been interfaced with the potato model, SIMPOTATO, and the simulated root activity dries the subsoil more rapidly than observed. 2DSOIL realistically simulated the distribution of water in soil under trickle irrigation.

Future Plans:
Modules will be added describing carbon and nitrogen turnover in agricultural soils as affected by traditional and prospective management practices. 2DSOIL will then be used to evaluate short and long term effects of these management practices on the fate and accumulation of organic nitrogen and carbon in soils in a CO_2-enriched environment.

Publications:
Timlin, D.J., Pachepsky. Ya, Acock, B., Lemon, H. and Tent, A. 1995. 2DSOIL - A Two-Dimensional Modular Simulator of Soil and Root Processes. In: Proceedings of the 1995 Workshop on Computer Applications in Water Management. 23 to 25 May, 1995. Colorado Water Resources Research Institute Information Series No. 79. Pg 174-178.

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Effect of Ozone Stress on Responses of Soybean and Cotton to Carbon Dioxide Enrichment

Principal Scientists: Allen S. Heagle and Joseph E. Miller,
Cooperating Scientists: Fitz Booker and Walter Pursley
ARS GCRP: Res. Areas: I ; Prog. Elements: C ; Objs/Tasks: 1/8, 4/1, 4/2, 4/5
CRIS Numbers: 6645-11000-004-00D

Problem: Research on effects of CO_2 enrichment has often been done where ground-level O_3 concentrations are high enough to injure plants. Effects of O_3 on plant response to CO_2 enrichment must be considered in order to accurately estimate effects of elevated atmospheric CO_2 on crop productivity and to interpret cause-effect relationships in CO_2 enrichment studies.

Approach: Field experiments were performed in open-top chambers with plants grown in 15-liter pots containing a mixture of sand, topsoil, and Metro Mix. Plants were exposed from within 3 days after emergence to physiological maturity to a range of CO_2 and O_3 concentrations in all combinations.

Findings:

Soybean Studies - 1993-1994

Essex soybean was tested in 1993 and Essex, Holladay, and Northrup King 6955 were tested in 1994. Elevated concentrations of O_3 caused foliar chlorosis and suppressed pod weight, seed yield, and stem weight, whereas elevated CO_2 generally increased plant biomass. Stimulatory responses to CO_2 were usually greater for plants stressed by O_3 than for plants not stressed by O_3. For example, in charcoal-filtered air seed yield for soybean was increased (compared to plants grown in ambient CO_2 concentrations) by 7, 15, and 16% at CO_2 concentrations of 481, 600, and 715 μLL^{-1}, respectively. Comparable values for plants in nonfiltered air were 24, 23, and 24 %, respectively, whereas values for plants in chambers with O_3 added were 30, 67, and 81%, respectively. The greater stimulatory effects of CO_2 enrichment for plants stressed by O_3 compared to those not stressed by O_3 was probably due to amelioration of O_3 stress by elevated CO_2.

Cotton Studies - 1995

Delta Pine 51 cotton was exposed to three concentrations of CO_2 and two concentrations of O_3. Fertilization with urea formaldehyde (38-0-0, N-P-K) produced three N levels as sub-plot treatments. Cotton growth and yield at the medium and high N levels was approximately two and three times greater respectively, than at the low N level. Stimulatory effects of CO_2 enrichment were greater for plants grown in chambers with O_3 added than for plants grown in charcoal-filtered air. For example, for plants in chambers with O_3 added and grown at medium N, seed cotton yield was 31, 52, and 48 g $plant^{-1}$ at 367, 514, and 657 uLL^{-1} CO_2, respectively. Comparable values for plants grown in charcoal-filtered air were 53, 54, and 53 g $plant^{-1}$, respectively. The O_3 x CO_2 interaction for yield was similar at low and medium N levels. However, at the high N level, CO_2 enrichment further increased vegetative growth resulting in decreased yield at both O_3 levels.

Publications:

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Shafer, S.R., M.M. Schoeneberger, S.J. Horton, C.B. Davey, and J.E. Miller. 1995. Interactions of *Rhizobium* and arbuscular mycorrhizal fungi with acidity and anion content of simulated rain on subterranean clover. Environ. Pollut. 92:55-66.

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Gas Exchange Characteristics of Soybean as Affected by Elevated CO_2 & O_3

Principal Scientist: Edwin L. Fiscus
Cooperating Scientist: Chantal D. Reid
ARS GCRP: Res. Areas: I ; Prog. Elements: C ; Objs/Tasks: 1/8, 3/2, 4/2
CRIS Numbers: 6645-11000-004-00D

Problem: How does elevated CO_2 affect soybean response to pollutant O_3?

Approach: CO_2 x O_3 interaction studies of photosynthesis and yield were conducted over a 3-year period. Soybean (cv Essex) were grown in open-top field chambers in ambient and a nominally doubled CO_2 concentration (360 vs 710 uL L^{-1}), in combination with charcoal-filtered (CF) air and a nominal 1.5 x ambient concentration of O_3 (mean of the daily 12h averages for the season were ~20 nL L^{-1} and ~70 nL L^{-1}, respectively).

In all three years final seed yield and midday leaf conductances were measured. Conductances were used to estimate the midday O_3 flux into the leaf. Total biomass was measured in two of the years. During one year, detailed measurements of photosynthesis were performed several times through the season. These measurements included A/C_i and A/PAR curves from which a variety of photosynthetic characteristics could be estimated.

Findings: Although an integrated interpretation of the results is not complete at this time, we can extract some useful generalizations: 1) total plant biomass increased in response to elevated CO_2, however there was no direct effect on seed yield in CF air; 2) although leaf conductance was consistently reduced by O_3 treatment, the stomatal limitation to photosynthesis was unaffected except by elevated CO_2 ; 3) midday O_3 flux calculations suggest a seasonal mean threshold for yield loss in the range of 20 to 30 nmol m^{-2} s^{-1}; 4) during reproductive growth a decrease in Rubisco capacity concurrent with an increase in saturating C_i suggests that RuBP regeneration was increasing while Rubisco capacity was being down regulated by both elevated CO_2 and O_3; and 5) elevated CO_2 has the capacity to ameliorate many of the effects of O_3 damage to photosynthesis, growth, and yield.

Future Plans: To determine the relationships between electron transport, triose phosphate utilization and RuBP regeneration in soybean exposed to elevated O_3 and CO_2.

Publications:

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FACE Project Status: Wheat Productivity and Energy and Water Balances

Principal Scientists: Bruce A. Kimball, Gerard W. Wall, Robert L. LaMorte, Sherwood B. Idso

Cooperating Scientists: Paul J. Pinter, Jr., Floyd J. Adamsen, Douglas J. Hunsaker, Francis S. Nakayama, Steve Leavitt, Tom Thompson, Allen Matthias, Roy Rauschkolb, Andrew Webber, John Nagy, George Hendrey, Keith Lewin, and about 15 more.

ARS GCRP: Res. Areas:	I;	Prog. Elements:	C;	Objs:	1;	Tasks:	8
	I;		C;		2;		8
	I;		D;		1;		2

CRIS Number: 5344-11000-005-00D

Problem: Determine the effects of the increasing atmospheric CO_2 concentration and any concomitant climate change on the future productivity, physiology, and water use of crops.

Approach: Free-air CO_2 enrichment (FACE) at 550 μmol/mol is being used to expose wheat crops growing in an open field to elevated CO_2, at ample and limiting levels of water (1992-94) and of soil nitrogen (1995-1997). Measurements are being made of physiological processes, growth, yield, energy and water relations, and soil carbon sequestration.

Started in 1987, open-top chambers are being used to expose orange trees to elevated CO_2 in the longest such experiment ever conducted.

FINDINGS: In FACE wheat plots supplied with ample water, evapotranspiration has been consistently lower, about 8% on the average. Net canopy photosynthesis was stimulated by an average 19 and 44% in well-watered and water-stressed plots, respectively, by elevated CO_2 for most of the 1992-3 growing season. No significant acclimation or down-regulation was observed. By mid-season the FACE plants had accumulated about 20% more above-ground biomass than Control plants, with root biomass stimulation somewhat more at about 27%. The FACE plants matured about a week earlier than the Controls in the well-watered plots. The FACE plants averaged 0.6°C warmer than the Controls from February through April in the well-watered plots, and we speculate that this temperature rise contributed to the earlier maturity. Because of the acceleration of senescence, there was a shortening of the duration of grain filling, and consequently, there was a narrowing of the final biomass and yield differences. The 20% mid-season growth advantage of FACE shrunk to about an 8% yield advantage in the well-watered plots, while the yield differences between FACE and Control remained at about 20% in the water-stressed plots.

The orange trees continue to produce nearly double the amount of fruit (and biomass) after 8 years of exposure to elevated CO_2 at 300 μmol/mol above ambient.

Future Plans: Another FACE wheat experiment at ample and limiting supplies of soil nitrogen will be conducted starting mid-December 1996 through May 1997.

Publications from 1995-1996:

PUBLISHED

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BELOWGROUND RESPONSES TO GLOBAL ENVIRONMENTAL CHANGE AND THE BIOGEOCHEMICAL DYNAMICS OF CARBON

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CRIS: 6420-11120-001-00D

PROBLEM: Atmospheric CO_2 increase has led to many uncertainties associated with Earth systems. Concerns encompass indirect effects related to predicted shifts in climate and direct effects on the biosphere, mainly terrestrial plant systems, crops being a chief concern. Plant growth is often stimulated when CO_2 concentrations rise and the stimulation of root development immediately leads to hypotheses of shifts in rhizosphere microbiology and soil processes. Enhanced plant growth further suggests greater delivery of C to soil, and thus potentially more soil C storage. However, little research has focused on belowground responses in agricultural ecosystems.

APPROACH: A five-year study of belowground responses to elevated atmospheric CO_2 is underway. An open top chamber crop exposure system was installed. Grain sorghum [*Sorghum bicolor* (L.) Moench] and soybean [*Glycine max* (L.) Merr.] are being exposed to two atmospheric CO_2 treatment concentrations -- ambient and twice ambient. Experiments are assessing crop growth above and below the ground; rhizosphere microbiology; nutrient relations; soil physical properties; water use; C and N dynamics; ground water quality; biogeochemical weathering; photosynthesis and chlorophyll fluorescence; and respiration and construction costs (amount of carbohydrate required to synthesize a unit of plant dry mass).

FINDINGS: Plant dry mass, energy content, composition, and construction cost were measured. Carbon dioxide increased phytomass for both species, had little effect on energy concentration (MJ m^{-2} plant) but caused large increases in plant energy per ground area (MJ m^{-2} ground), did not affect specific growth cost (kg carbohydrate kg^{-1}), but greatly increased growth cost per ground area (kg carbohydrate m^{-2} ground) because growth was enhanced. Transpiration (measured with stem flow gauges) was significantly reduced for both species by elevated CO_2; at ambient and twice ambient levels of CO_2, sorghum average daily transpiration was 1128 and 772 g m^{-2} d^{-1} and soybean, 731 and 416 g m^{-2} d^{-1}, respectively. Nitrate N concentrations in soil solution was monitored at a depth of 90 cm. Significant differences were observed; total dry mass, total N content, and C:N ratio of residue were increased by elevated CO_2. Results indicate that retention of N in organic pools due to elevated CO_2 could reduce nitrate concentration in groundwater beneath agro-ecosystems as indicated by nitrate movement. Carbon isotope techniques using $\delta^{13}C$ were used to track input of new C into the soil system. After two years, elevated CO_2 increased new C with grain sorghum, 194 and 46 g m^{-2}, but decreased with soybean, 111 and 331 g m^{-2}, for elevated and ambient CO_2, respectively. These data indicate potential for soil C storage in agro-ecosystems, but the mechanisms for C storage may be different for different crop species.

FUTURE PLANS: (1) complete remaining year of this study; (2) study implications of increased CO_2 for residue management and soil C sequestration, including physicochemical properties of crop residue, and (3) assess biogeochemical mineral weathering in CO_2-enriched agro-ecosystems.

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Genetic Differences in Response of Mesquite Biotypes to Elevated Carbon Dioxide

Principle Scientists: C. R. Tischler, R. E. Pennington,

Cooperating Scientists: H. B. Johnson, H. W. Polley

ARS GCRP: Res. Area: I; Prog. Element: C; Objective: 2; Task 1.

Cris Number: 6206-11210-001-00D

Problem: We have observed marked differences among individual biotypes of mesquite with regards to seedling growth response to elevated carbon dioxide (CO_2). Others have made similar observations for diverse species. Evolutionary theory predicts that characteristics which improve survival and reproductive success of individuals should subsequently increase in frequency in a species. Through natural selection, the frequency of characteristics important to enhanced growth responses to elevated CO_2 may be increasing and may contribute to the proliferation of genotypes whose overall response to elevated CO_2 is much greater than that predicted by the study of present-day genotypes.

Approach: Molecular techniques include methods such as RAPD PCR to identify genetic markers associated with a particular phenotype, even when the biochemical or physiological basis for the particular phenotype is unknown. A collection of seed from ancient and young mesquite trees covering a broad geographic expanse is being assembled. Half-sib families with superior response to elevated CO_2 are being identified. DNA from superior performers is being subjected to RAPD PCR analysis to identify informative polymorphisms for response to elevated CO_2.

Findings: Protocols for isolation of DNA from three species of mesquite have been perfected. Seedling growth rates of sixteen half-sib honey mesquite families grown in ambient and elevated CO_2 atmospheres, differed significantly in response to atmosphere. Individual variation within families suggests that multiple factors confer incremental improvement in overall response to elevated CO_2. RAPD analyses of mesquite biotypes from different geographical locations have demonstrated site- and age- specific polymorphisms. Polymorphisms in samples from honey mesquite seedlings from the Joronada Experimental Range (Eastern New Mexico) suggest that gene introgression from velvet to honey mesquite may have occurred.

Future Plans: Germplasm representing a significant cross section of the east to west range of honey mesquite will be characterized for response to elevated CO_2. Seedling growth rate, leaf photosynthetic rate, and carbon isotope discrimination will be determined in outstanding and average progeny of a number of half-sib families in an attempt to detect genes for CO_2 responsiveness donated by the pollen parent (Honey mesquite is self-incompatible). Comparisons of results from several families may identify QTL (quantitative trait loci) for CO_2 response which may be difficult to characterize

physiologically, but which will be useful in predicting invasiveness of specific mesquite populations as CO_2 increases.

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Impacts of Rising Atmospheric CO_2 Concentration on Transpiration

Principle Scientists: Hyrum B. Johnson, H. Wayne Polley, Charles R. Tischler

ARS GCRP: Res. Area: I; Prog. Element: C; Obj.: 2; Tasks: 3, 7; Obj.: 3; Task 2

CRIS Number: 6206-11210-001-00D

Problem: Atmospheric CO_2 concentration has doubled since the last ice age and increased about 30% during the last 200 years to the present 350 ppm. It may double again during the next century. Rising CO_2 concentration often reduces stomatal (leaf) conductance. When leaf area does not increase, rising CO_2 may slow soil water depletion. Processes ranging from nutrient cycling to the dynamics of plant species may be affected in water-limited ecosystems, like rangelands in the southern Great Plains and southwestern U.S.

Approach: Rangeland and other plants of differing photosynthetic pathway, growth form, and longevity were grown over atmospheric CO_2 concentrations representative of the last glaciation to levels expected during the next century. We measured relationships of stomatal conductance to CO_2 concentration and investigated feedbacks of rising CO_2 on leaf area that could offset effects of stomatal closure on plant transpiration.

Findings: Increasing CO_2 concentration usually reduced stomatal conductance, consistent with prior observations. But, the decline in conductance per unit increase in CO_2 depended on the concentration range considered, photosynthetic pathway of plants, and presence or absence of physiological "acclimation" following growth at different CO_2 levels. Per unit increase in CO_2, stomatal conductance declined more over subambient concentrations representative of the past than elevated levels expected in the future. In the C_4 bunchgrass little bluestem (Schizachyrium scoparium), for example, conductance declined three-times more per unit increase in CO_2 concentration over subambient than elevated levels. Absolute responses of conductance to CO_2 usually were greater in C_3 than C_4 species and in plants in which leaf gas exchange "acclimated" or down-regulated when grown at higher CO_2 concentrations. Gas exchange of huisache (Acacia smallii) down-regulated when the woody legume was grown at 700 ppm CO_2. At a given CO_2 concentration, leaf photosynthesis and conductance were lower in plants grown at 700 than 350 ppm. As a result, the decline in stomatal conductance from 350 to 700 ppm was twice that obtained by temporarily exposing plants grown at today's concentration to 700 ppm.

Leaf area may increase to offset the water saved by closing stomates if essential plant resources are available. This occurred in wheat and huisache. On many rangelands, however, growth and leaf area are limited by nitrogen (N) as well as water. Unless plants reallocate N from other tissues to leaf production or produce leaves with lower N concentrations, leaf growth may respond little to CO_2. Transpiration per unit plant N should decline as a result. Water loss per unit of plant N declined as CO_2 rose from the glacial to current concentration in two cultivars of wheat and the woody legume mesquite (Prosopis glanulosa), but did not change in cheatgrass (Bromus tectorum).

Future Plans: Evapotranspiration, soil water levels, and soil respiration and N mineralization will be monitored in a successional prairie exposed to a gradient in atmospheric CO_2 from glacial to elevated concentrations. We will evaluate feedbacks of atmospheric change on water dynamics of the ecosystem and related processes.

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Carbon and Nitrogen Cycling on the Shortgrass Prairie

Principle Scientists: J.A. Morgan and G.E. Schuman, Rangeland Resources Research

Cooperating Scientists: R.H. Hart, D.R. LeCain, J.S. Reeder

ARS GCRP: Research Area I; Program Element C; Objective 2: Tasks 3-7, 10, Objective 3: Task 3.

CRIS Numbers: 5409-11210-001-00D

Problem: As atmospheric greenhouse gasses continue to increase and recent reports suggest climatic change may finally have begun, there is a critical need to understand the biogeochemistry of this process and how the earth's ecosystems might respond and interact with it. As rangeland scientists, we are primarily interested in how these changes and their interaction with management will affect the long-term health and sustainability of our native grasslands.

Approach: A suite of inter-related studies, from carefully-controlled growth chamber work to field studies involving long-term grazing trials were instigated to study various aspects of C and N cycling on the shortgrass prairie.

Findings: In growth chamber CO_2-enrichment studies, photosynthesis and growth of C_3 and C_4 grasses of the shortgrass steppe were stimulated similarly by CO_2 when grown under water-deficits. The degree of responsiveness of these grasses to CO_2 depends on temperature, with global warming favoring the warm-season, C_4 species. Where growth was significantly stimulated by CO_2 enrichment, plant N concentrations declined. These findings suggest that under the characteristic water-deficit conditions of the prairie, most grasses will experience increased growth, but the resultant forage may have slightly lower crude protein concentration, and thus, lower quality.

In field studies, we observed greater soil C and N in the surface 30 cm of soil under grazing compared to non-grazed areas. Aboveground components generally contained greater quantities of C and N in the non-grazed exclosures than in grazed pastures. The total C and N balance of this rangeland system exhibited no significant differences regardless of grazing strategy or stocking rate. Chamber determinations of carbon exchange rate indicated a net photosynthetic advantage in the spring for grazed pastures. These studies suggest moderate grazing has no deleterious effect on soil C and N stores, and may enhance it in some cases..

Future Plans: CO_2 enrichment/ modeling studies will be continued, and expanded to an open-top chamber facility at the Central Plains Experimental Range (funded, in part, by NSF) where plant physiological responses, competition between native grasses, soil nutrient cycling, and trace gas exchange will be studied at two CO_2 concentrations, present-day ambient, and twice that level. Field studies on C and N cycling on grazed and non-grazed pastures will also continue, and will be expanded to examine nutrient cycling in more detail through isotopic labeling. This work will be evaluated with the chamber and Bowen Ratio/Energy Balance determinations of carbon fluxes to better understand how grazing affects C and N cycling.

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CARBON-14 DATING OF SOIL ORGANIC MATTER FROM THE WALNUT GULCH EXPERIMENTAL WATERSHED

Principle Scientists: M. Weltz
Cooperating Scientists: S. Biedenbender
ARS GCRP: I.C.2.6
CRIS Numbers: 5342-13610-005-00D

Problem: Since the turn of the century, many grasslands in the southwestern United States have been transformed to savannas or shrublands. This change in vegetation has often been accompanied by accelerated erosion and loss of the grazing resource. However, the extent and causes remain controversial. In many areas the only information about past vegetation communities is anecdotal, and vegetation reconstructions based on packrat midden, fossil, and stratigraphic data produce incomplete or conflicting knowledge of past vegetation assemblages. Suggested mechanisms for woody plant invasion into grasslands include overgrazing, fire suppression, climate change, and increasing atmospheric carbon dioxide. A long-term vegetation chronology would provide a perspective for evaluating recent vegetation change, land use, and erosion, as well as insights into climate and atmospheric change and their effects on vegetation dynamics.

Approach: Research is being undertaken to investigate the post-glacial grass-shrub community composition at the Walnut Gulch Experimental Watershed in southeastern Arizona. Soil profiles will be studied in present grass and shrub vegetation types. Past grass-shrub vegetation will be determined from the delta carbon-13 values of soil organic matter at various depths. Plants which photosynthesize via the C3 have a distinctly different ratio of carbon-13 to carbon-12 in their tissues than plants which photosynthesize via the C4. On Arizona grasslands, the primary C3 species are shrubs and the primary C4 species are warm-season perennial grasses. The delta carbon-13 signature of soil organic matter reflects that of the contributing vegetation. For each depth in the soil profiles, this study will also evaluate the percent sand, silt, and clay, total organic carbon, and the biomass and delta carbon-13 signature of roots. The delta carbon-13 signatures for the present plant communities at the soil profile sites will also be ascertained.

Future plans: Additional financial support is required to determine the radiocarbon-14 ages of the soil profiles. It is critically important to obtain corresponding carbon-14 dates for each sampling depth in order to establish the time frame for the grass-shrub vegetation assemblages revealed by the delta carbon-13 signatures. The relative ages of the soil strata not only provide a chronological framework for vegetation and climate, but may also indicate the degree of erosional removal of younger material from the soil surfaces. Dating the soil organic matter will make it possible to compare the past grass-shrub vegetation found using carbon-13 ratios at the Walnut Gulch Experimental Watershed with results obtained using different methods from various sites. For this study, we would like to date the surface and lowest layers and the horizon boundaries for each profile using a modified thin-layer sampling method.

A Two-Dimensional Model of Leaf Gas Exchange that Accounts for Anatomical Changes.

Principal Scientist: Basil Acock

Cooperating Scientist: Ludmila B. Pachepsky

ARS GCRP: Res. Area: I; Prog. Element: C; Obj.: 3; Tasks: 5, 6, 7 and 8.

CRIS Number: 1270-66000-013-00D

Problem:
Nearly all existing models of photosynthesis treat the leaf as a plane that absorbs CO_2 and loses water vapor. The diffusion of these gases to and from the leaf is represented in the models by a conductance (or resistance) to gas movement. These simplifications work well only if leaf internal geometry is constant. However, the number and density of cells per unit leaf area change with environmental conditions, particularly CO_2 concentration ([CO_2]). When leaf geometry changes, the gas diffusion parameters change in unpredictable ways. Thus, extant photosynthesis models cannot be calibrated in current ambient conditions and then used to predict plant response to future climates. Consequently a model of photosynthesis which describes in detail the main physical, physico-chemical, and biochemical processes is needed.

Approach:
Develop a two-dimensional model of leaf morphology and gas exchange by mapping the leaf cross section onto a dense grid of points and giving each point appropriate properties. Use a modular approach to assemble the complete model, so that submodels can be added or deleted easily. Validate the model for responses to [CO_2], light, temperature, vapor pressure deficit, and leaf water status, and use it to make predictions about crop responses to climate change.

Findings:
The 2DLEAF model was validated for soybean, tomato and cotton. Stomata were added to the second side of the model leaf so that 2DLEAF can simulate amphistomatous leaves. Also, decrease in light intensity from top to bottom of the leaf was added. The new amphistomatous model was used to evaluate the differences in gas exchange occurring on the two sides of the leaf. Functional differences between the stomata on the two sides of the leaf was shown to be likely. A large database of leaf cross-sections for native species in various habitats was examined to see how the various leaf anatomies might affect photosynthesis. The variable having the most effect was cell area index: the ratio of cell surface area to leaf surface area.

Future Plans:
Experimental and theoretical work is planned to show the effect of growth environment on leaf geometry and leaf gas exchange in agronomic plants. Criteria will be developed to assess the likely response of new plant cultivars and genetically engineered plants to a changed climate.

Publications:
Pachepsky, L. B. and Acock, B. Modeling of photosynthesis and transpiration as processes occurring in a geometrically organized set of parenchyma and spongy mesophyll cells and regulated by guard cells. Molecular Biology of the Cell, 5:109. 1994.

Pachepsky L.B. and B. Acock. 1995. An adequate model of photosynthesis. 2. The dependencies of parameters values on environmental factors. Agricultural Systems 50:227-238.

Reddy, V.R., L.B. Pachepsky, and B. Acock. 1995. Response of crop photosynthesis to CO2, temperature, and light: Experimentation and modeling. HortScience 29:1415-1422.

Pachepsky, L B., J.D.Haskett, and B.Acock. 1995. A two-dimensional model of leaf gas exchange with special reference to leaf anatomy. Journal of Biogeography 22:209-217.

Pachepsky, L. B., Pachepsky, Y. A. and Acock, B. The 2DLEAF code for simulating carbon dioxide and water vapor flow in the two-dimensional leaf interior and boundary layer, version 1.1. USDA and Duke University. 1996. (Documentation of the model.)

Pachepsky, L. B. and Acock, B. A model 2DLEAF of leaf gas exchange: development, validation, and ecological application. Ecological Modelling ??:??-??, 1996. (in press)

Pachepsky, L. B. and Acock, B. Effect of leaf anatomy on leaf gas exchange: numerical experiments with the 2DLEAF model. Ecological Modelling (in review).

Scaling stomatal responses to CO_2 from the leaf to the field.

James A. Bunce
Climate Stress Laboratory

ARS GCRP Res. Area: I; Prog. Element: C; Obj: 3; Task: 1

CRIS: 1270-21000-015-00D

PROBLEM:

One of the primary effects of increasing atmospheric carbon dioxide concentration on plants is a reduction in stomatal conductance to water vapor. While this response is well documented for plants grown at the current carbon dioxide concentration, there is little information to indicate whether stomatal responses to environment are modified by long-term exposure to elevated carbon dioxide.

APPROACH:

For barley, wheat, potato and sorghum determine whether long-term exposure to elevated carbon dioxide in the field alters maximum stomatal conductance at the growth CO2, and, if so, whether this is caused by photosynthetic acclimation to elevated carbon dioxide. Determine the biochemical nature of any photosynthetic acclimation observed.

FINDINGS:

Both stomatal and photosynthetic acclimation to elevated CO2 occurred in barley and wheat in the field. Both stomatal conductance and photosynthesis were reduced after long-term exposure to elevated carbon dioxide compared to the short-term responses to elevated carbon dioxide found in plants developed at the current ambient CO2 concentration. The acclimation of photosynthesis resulted from reduced RuBisco protein content and activity per unit of leaf area, which accompanied the reduction in total soluble protein content at elevated CO2. The degree of photosynthetic acclimation was greatest late in the growth cycle in both species, but occurred even early in vegetative growth. The amount of acclimation in stomatal conductance was proportional to the amount of acclimation of photosynthesis in wheat, but not in barley. However, the cause of the proportionality in wheat remains unclear, because it is not caused by stomatal response to internal CO2. The gain of the internal CO2 feedback system is not sufficient in either species to explain the acclimation of stomatal conductance by photosynthetic acclimation.

PLANS:

Determine whether stomatal and photosynthetic acclimation occur in sorghum and potato in the field. Determine the nature of any photosynthetic acclimation to elevated carbon dioxide observed in potato and sorghum in the field, and whether photosynthetic acclimation causes any stomatal acclimation.

PUBLICATIONS:

Coupled Modeling of the Carbon and Energy Balance from Plant to Basin Scales

Principal Scientist:	William P. Kustas
Cooperating Scientists:	Xiwu Zhan
	Basil Acock
ARS GCRP:	Res. Area: I; Prog. Elements: D; Objs.: 1; Tasks: 1,4
CRIS Numbers:	1270-13610-004-00D
	1270-13660-005-00D

Problem: A simulation model coupling both the carbon and energy balance for vegetated surfaces is required for better understanding the linkages between hydrologic and plant physiological processes. The model must capture the essential physical processes of the energy and carbon balance, but needs to be simple enough in order to evaluate the relationship between the carbon and energy balance at increasing spatial scale with remote sensing.

Approach: Data collected from large-scale field experiments conducted in different climatic regions in recent years will be used to test and validate a coupled carbon-energy balance model of varying complexity that uses remote sensing data. The models will be run from the flux station up to the basin scale and will be validated with surface measurements and estimates determined by atmospheric boundary layer models.

Findings: A coupled carbon-energy balance model using remote sensing data has been developed and tested with field data collected from a semiarid rangeland and subhumid grassland basin. The model performed satisfactorily for the subhumid grassland, showing good agreement between simulated and measured energy and carbon fluxes. However, the model had difficulty in computing the energy fluxes for the semiarid site containing shrub vegetation. It was determined from independent measurements that the model significantly underestimated vegetation transpiration for the shrub ecosystem, and therefore required adjustments to the stomatal conductance algorithms. Furthermore, the type of soil evaporation algorithm being used had a significant impact on the modeled fluxes . These findings suggest that more work is needed in developing and testing soil evaporation and stomatal conductance algorithms for different surfaces.

Future Plans: Simplified versions of the coupled carbon-energy balance model will be developed in order to run the model efficiently using large remote sensing data sets containing 10^5 to 10^6 pixels of vegetation and soils information. At the local scale, model output will be compared to observations and more detailed simulation models. The spatially-distributed fluxes will be assessed by comparing the output with measured fluxes and with simpler, more empirically-based, models and those computed for the basin using atmospheric boundary layer models.

Publications:

Norman, J. M., W. P. Kustas and K. S. Humes. 1995. A two-source approach for estimating soil and vegetation energy fluxes from observations of directional radiometric surface temperature. Agricultural and Forest Meteorology. 77:263-293.

Kustas, W. P., K. S. Humes, J. M. Norman and M. S. Moran. 1996. Single-and dual-source modeling of surface energy fluxes with radiometric surface temperature. Journal of Applied Meteorology. 35:110-121, No. 1.

Zhan, X. and W. P. Kustas. 1996. Modeling CO_2, water vapor and sensible heat fluxes over land surface using remote sensing data. Preprints of the American Meteorological Society 12th Conference on Micrometeorology and Aerobiology. January 15-19, Atlanta, GA pp. J85-J88.

Zhan, X., W. P. Kustas, and K. S. Humes. 1996. An intercomparison study on models of sensible heat flux over partial canopy surfaces with remotely sensed surface temperature. Remote Sensing of Environment. In Press.

Simulating organic carbon dynamics with EPIC

Principle Scientists: Dr. Jimmy Williams

Cooperating Scientists: Dr. Pierre-Philippe Claude
Dr. Jeffrey J. Lee
Dr. Verel Benson
Dr. Cesar Izaurralde

ARS GCCP: Res Area: Structure and Function; Prog. Elements: Integrated Systems; Objective 1; Task 2.

CRIS Number: 6206-61660-002-00D

Problem: Estimation of soil organic carbon changes resulting from soil management practices.

Approach: Verification and improvement of soil organic carbon simulation with the EPIC agricultural simulation model.

Findings: EPIC has been used to simulate changes in soil organic carbon for a wide range of management options. Comparisons have been made to long-term summer fallow/ winter wheat rotations, and long-term management plots on the Canadian prairies. In addition, EPIC has been used to estimate the effect of converting pastures to pine tree plantations in the Southeastern United States, and the potential of various agricultural systems to compensate for climatic change.

Future Plans: EPIC shall continue to be improved and tested to simulate management and climatic effects on soil organic carbon sequestration.

Publications:

Claude, P.P., and J.J. Lee. 1996. A long-term comparison of estimates of soil organic carbon and nitrogen and crop yield by EPIC and CENTURY. (In Preparation).

Lee, J.J. 1996. The potential effects of afforestation on the carbon budget of the south central United States. (In Preparation).

Lee, J.J., and V. Benson. 1996. Soil erosion and climate change: Assessing potential impacts and adaption practices. (In Preparation).

Izaurralde, R.C., W.B. McGill, D.C. Jans-Hammerstein, K.L. Haugen-Kozyra, R.F. Grant, and J.C. Hiley. 1996. Development of a technique to calculate carbon fluxes in agricultural soils at the ecodistrict level using simulation models and various aggregation methods. Interim Report. University of Alberta, Edmonton, Alberta, Canada.

Progress Report, Program Element II, Objective 2, Interactively utilize natural resource models as a basis for developing mitigation and adaptive strategies to avoid or minimize the negative effects, and optimize the positive effects of global change on managed ecosystems within the global environment.

Development and Validation of an Interactive Climate-Vegetation-Soil Model to Predict Potential Climate Change Effects on Early Plant Establishment

Stuart Hardegree, Greg Johnson, Gerald Flerchinger, Clayton Hanson, Ross Wight, Fred Pierson
Northwest Watershed Research Center, Boise, Idaho, May 19, 1996

Problem:

Climate change is expected to have a large impact on water resources through its effect on the hydrologic cycle. Historical changes in regional climate have either resulted in migration or extinction of wildland plant species. Current predictions of future climate indicate a much faster rate of change than has occurred in the past. Rapid change may limit natural species migration, adversely affect plant productivity and native plant diversity, and result in a redistribution of wildland plant species and plant community types. Opportunistic weedy species are especially well suited to take advantage of ecosystem disturbance caused by climate change. The Bureau of Land Management estimates that resource values are already impaired or threatened by the proliferation of weedy annual grasses on millions of acres of rangeland in the Great Basin and Columbia Plateau. New technology must be developed: to assess potential climate change effects on the distribution of wildland plant species; and to restore and maintain native plant diversity under current and future climatic scenarios.

Approach:

Critical factors determining successful establishment of wildland plants are the spatial and temporal distribution of soil heat and moisture relative to growth response of both desirable plant species and weedy competitors. The general approach taken in this program is to develop an interactive soil-vegetation-climate modeling system that accounts for the seasonal and yearly variability in macroclimatic variables; topographic and edaphic effects on seedbed microclimate; competition for moisture; and the inter and intraspecific variability in growth response of desirable and undesirable plant species.

Findings:

Seeds of 4 native perennial grasses and cheatgrass have been evaluated for response to constant, alternating, sine wave pattern, and field-variable temperature regimes and for response to combined conditions of temperature, water potential and specific salt effects. These studies form the framework for a predictive model of germination response based upon thermal and hydration time requirements. The temperature component of this model has been tested using field-variable temperature regimes.

Procedures have been developed to enhance germination rate of native perennial grasses to make them more competitive with cheatgrass for early spring moisture. Native grass seeds have been induced to germinate as much as 8 days earlier than nontreated seeds in a low temperature test environment. Field trials for 12 planting dates over a two year period have confirmed that treated seeds emerge more rapidly than untreated seeds.

Intercomparisons of four meteorological variables (daily maximum and minimum air temperature, precipitation and solar radiation) were conducted between the USCLIMATE and CLIGEN climate generator models and historical climate data. Both generators replicated mean values quite well, but variances often are poorly modeled. CLIGEN replicates only about 20% to 30% of the actual standard deviation of many variables while USCLIMATE replications were mostly between 60% and 90% of actual. Both generators were found to replicate extreme values quite well.

Instrumentation for field validation and calibration of seedbed microclimatic models has been completed at the Orchard Field Test Site in southeastern Ada County, Idaho. Three blocks of experimental plots, one in each of three soil types (loamy sand, sandy loam, silt loam) have been instrumented with thermocouples and TDR probes to 100-cm depth, infra-red soil-surface-temperature sensors, precipitation, wind, solar radiation, humidity and air temperature sensors. The Simultaneous Heat and Water (SHAW) model was tested to determine how well it simulates small scale influences of grass growth-form on near-surface soil temperature and moisture conditions.

A soils and weather database has been compiled for the Snake River Plain region of Idaho. A 30 year weather record has been used to parameterize the SHAW model for the soil types at the Orchard Field Test Site. Seedbed microclimatic profiles of temperature and moisture at seeding depth have been

developed as input into a hydrothermal-time model for seed germination of native perennial grasses. Probabilistic descriptions of germination success for the simulated period have been developed for a burn-rehabilitation scenario on BLM land in the Snake River Plain.

Future Plans:

Further experiments will be conducted to test and validate seedling emergence models for native bunchgrasses and their weedy competitors. Seed-treatment techniques will be scaled-up to apply to commercial-scale seed lots. The Orchard seedbed database will provide a robust validation of the soil water component of the SHAW model. Sensitivity analysis will be performed to determine applicability of SHAW to burn-rehabilitation planning on BLM lands in Idaho. A system will be developed to distribute weather records and climate-generator parameters over space for the Snake River Plain region of Idaho. Interactive weather, soil, and plant models will be run to develop probabilistic descriptions of revegetation success in the Snake River Plain given historical and projected future climate scenarios.

Recent Publications:

Emmerich, W.E. and S.P. Hardegree. 1996. Partial and full dehydration impact on germination of four warm-season grasses. Journal of Range Management (In Press).

Hardegree, S.P. 1994. Drying and storage effects on germination of primed grass seeds. Journal of Range Management 47:196-199.

Hardegree, S.P. 1994. Matric-priming increases germination rate of Great Basin native perennial grasses. Agronomy Journal 86:289-293.

Hardegree, S.P. 1994. Germination enhancement of perennial grasses native to the Intermountain region. Proceedings: Symposium on the Ecology, Management and Restoration of Intermountain Annual Rangelands. Boise, ID, May 18-22, 1992.

Hardegree, S.P. 1995. Datalogger control of environmental chambers for variable-temperature germination experiments. Journal of Range Management 48:554-556.

Hardegree, S.P. 1996. Optimization of seed hydration treatments for enhancement of low-temperature germination rate. Journal of Range Management 49:87-92.

Hardegree, S.P., F.B. Pierson, G.L. Johnson, G.N. Flerchinger and C.L. Hanson. 1996. Seedbed microclimatic modeling for burn rehabilitation planning in the Great Basin region of the western United States. In: Proceedings of the Fifth International Rangeland Congress. Volume I. Neil West (ed.). Salt Lake City, UT, July 23-28, 1995. pp. 207-208.

Hardegree, S.P., F.B. Pierson, G.L. Johnson, G.N. Flerchinger, C.L. Hanson, and J.R. Wight. 1996. Effects of climate change on early plant establishment. Maintenance and restoration of native plant communities in the Great Basin. In: Global Change and Agriculture: Soil, Water, and Plant Resources, Volume III: Papers and Presentations. USDA-ARS-Global Change Research Program. pp. 34-42.

Hardegree, S.P., M. Shipitalo, S. Knight and C. Feldhake. 1994. Biological processes and hydrology: scientific challenges and research opportunities. In: Proceedings USDA-ARS Conference on Hydrology. Denver, CO Sept. 13-15, 1993.

Johnson, G.L., C.L. Hanson, S.P. Hardegree and E.B. Ballard. 1996. Stochastic weather simulation: Overview and analysis of two commonly used models. Journal of Applied Meteorology. (In Press).

Pierson, F.B., S.P. Hardegree, G.N. Flerchinger and J.R. Wight. 1995. Spatial and temporal variability of seedbed microclimate on rangelands: characterization and modeling. In: Proceedings of the Fifth International Rangeland Congress. Volume I. Neil West (ed.). Salt Lake City, UT, July 23-28, 1995. pp. 446-447.

Estimating Climate Change Effects on Water Supplies Using the Snowmelt Runoff Model (SRM)

Principle Scientist: Albert Rango
Cooperative Scientist: Jaroslav Martinec
ARS GCRP: Res. Areas: III; Prog. Elements: A; Objs.: 1; Tasks: 4.
CRIS Numbers: 1270-13610-002-00D

Problem: As a result of increasing atmospheric CO_2, significant global warming along with regional changes in precipitation and cloudiness are expected. Both increases in temperature and changes in precipitation input will affect the accumulation and ablation of mountain snowpacks, the major source of irrigation water supply for agriculture, runoff for hydropower generation, and domestic water supplies in the western half of the United States. The exact effect of the climate change on snowmelt runoff is very difficult to predict.

Approach: Some common features of the climate change scenarios are chosen as input to the Snowmelt Runoff Model (SRM), a simple snowmelt runoff model which has been validated on over 60 basins worldwide. Three variables (temperature, precipitation, and snow covered area) are input to SRM to estimate the hydrologic response under conditions of climate change. Several representative basins in the mountainous western North America have been chosen for study.

Findings: In the Rio Grande basin of Colorado, conventional depletion curves of snow cover will change under new climate regimes because of a warmer melt season as well as a warmer winter season. The warmer winter season features storm events with less snow and more rain and more winter snowmelt and runoff which results in less snow water equivalent on April 1 (if total precipitation is assumed unchanged). SRM can be used to compute year-round hydrographs in the existing climate and in an assumed warmer climate of the future. One reason for this is that SRM is a non-calibrated model which allows physical estimation of parameters under the projected conditions of the future climate.

After climate change, the Rio Grande hydrograph shows a major shift of runoff from the summer half year to the winter half year while the peak flow moves from June to April-May. In a high runoff year before climate change, 92% of the annual flow occurs in the summer half year and 8% in the winter half year. After a +4°C increase in temperature, the summer half year has 87% and winter has 13%. In an average year, 87% of the runoff occurs in summer and 13% in winter before climate change and 72% and 28% after a +4°C temperature increase. In a drought year, the summer value is 76% before climate and 71% after. In winter the values are 24% and 29%, respectively. Very similar patterns in snow water equivalent accumulation on April 1 are also shown by SRM.

Future Plans: The methodology developed on the Rio Grande basin will be extended to other representative snowmelt basins in North America in the other major snow accumulation and ablation regimes. Comparison to hydrologic responses developed by other models will be attempted.

Publications:

Josberger, E. G., Gloersen, P., Chang, A. T. C., and Rango, A., 1996. The effects of snowpack grain size on satellite passive microwave observations from the Upper Colorado River Basin. Journal of Geophysical Research, 101(C3), 6679-6688.

Rango, A. and Martinec, J., 1995. Revisiting the degree day method for snowmelt computations, Water Resources Bulletin, 31(4),657-669.

Wergin, W. P., Rango, A., and Erbe, E. F., 1995. Observations of snow crystals using low temperature scanning electron microscopy, Scanning, 17(1),41-49.

Rango, A., Martinec, J., and Roberts, R., 1995. Climate effects on future runoff regimes of Pacific mountain tributaries, Proceedings of the Symposium on Water Resources and Environmental Hazards: Emphasis on Hydrologic and Cultural Insight in the Pacific Rim, American Water Resources Association, Honolulu, HI, pp. 161-172.

Rango, A., 1995. Effects of climate change on water supplies in mountainous snowmelt regions, World Resource Review, 7(3), 315-325.

Martinec, J. And Rango, A., 1995. Seasonal runoff forecasts for hydropower based on remote sensing, Proceedings of the 63rd Annual Western Snow Conference, Reno, NV, pp. 10-20.

Rango, A., Wergin, W. P., and Erbe, E. F., 1995. Snow crystal imaging using scanning electron microscopy: I - Precipitated snow, Hydrological Sciences Journal, 41(2), 219-233.

Rango, A., Wergin, W. P., and Erbe, E. F., 1995. Snow crystal imaging using scanning electron microscopy: II - Metamorphosed snow, Hydrological Sciences Journal, 41(2), 235-250.

A Methodology for Using Field-Scale Models to Predict Yields Over Large Areas.

Principal Scientist: Basil Acock

Cooperating Scientist: Jonathan Haskett and Yakov A. Pachepsky

ARS GCRP: Res. Area: III; Prog. Element: A; Obj.: 2; Task: 5.

CRIS Number: 1270-66000-013-00D

Problem:
Crop models that respond mechanistically to carbon dioxide concentration ([CO_2]), temperature, rainfall, light and other environmental variables are all field-scale models. To make predictions about crop response to climate change over large areas, we need to develop methods for aggregating the results from these models over large areas, accounting for soil and weather variability. All large area yield predictions published so far are actually results for one or a few "typical" fields multiplied by the appropriate area.

Approach:
Devise and test one or more methods of using field-scale crop models to make large area predictions. Use the method to predict crop responses to climate change using the future climate scenarios predicted by various general circulation models (GCMs).

Findings:
Earlier, we developed a method of aggregating data from individual soils into soil associations using the beta distribution to describe the combined frequency distributions for values of key variables. We then sampled these beta distributions at random to obtain soil variables for crop model runs. Multiple runs were used for each soil association, and these were done on a Cray computer at Laurence Livermore Lab using time donated by the Dept of Energy. The soybean crop model GLYCIM was used to predict soybean yields for each county in Iowa for the next 50 years using climates predicted by GCMs from: the Goddard Institute for Space Studies (GISS); the Geophysical Fluid Dynamics Laboratory (GFDL); and the United Kingdom Meteorological Office (UKMO). We developed a technique to downscale from the monthly weather projections of the GCM's to the daily weather variables needed to run GLYCIM. Yield variability increased as climate changed. [CO_2] was the main determinant of yield response. When climate change was simulated without increase in [CO_2], yields remained constant in the GISS and GFDL scenarios and decreased in the UKMO scenario.

Because the method of making multiple runs of a crop model is so computer-intensive, the use of a neural network was investigated. The trained neural network was able to reproduce 97% of the variability in GLYCIM.

Future Plans:
No further work is planned. The methodology has been developed, tested and published.

Publications:
Haskett, J. D., Pachepsky, Y. A. and Acock, B. Use of the beta-distribution for parameterizing variability of soil properties at the regional level for crop yield estimation. Agricultural Systems 48:73-86, 1995.

Haskett, J. D., Pachepsky, Y. A. and Acock, B. Estimation of soybean yields at county and state levels using GLYCIM: a case study for Iowa. Agron. J. 87:926-931, 1995.

Haskett, J.D., Pachepsky, Y.A. and Acock, B. Climate change effects on Iowa soybean production: a comparison of scenarios using GLYCIM. Agron. J. 88: ??-??, 1996

Haskett, J.D., Pachepsky, Y.A. and Acock, B. Use of artificial neural networks to simulate soybean crop yield as affected by global change. Global Change Biology (in review)

Title: Carbon dioxide fluxes on seeded and native pastures on the Northern Great Plains.

Principle Scientists: A. B. Frank and J. F. Karn

ARS GCRP: Res. Areas III; Prog. Elements: A; Objs: 3; Tasks: 1

CRIS No. 5445-21000-005-00D

Problem: The role of Northern Great Plains native (wheatgrass-needlegrass-blue grama) and managed improved grasslands in the global carbon balance has not been fully characterized.

Approach: The CO_2 Bowen ratio energy balance approach is being used to measure CO_2 fluxes from grazed and nongrazed native mixed prairie grassland and from seeded 'Rodan' western wheatgrass pastures.

Findings: The CO_2 Bowen Ratio Energy Balance system was put in operation on May 22, 1995. The data have been summarized through development of peak standing crop on July 5. Vegetation composition was similar for both native grazed and nongrazed pastures. Peak LAI was 1.0 and 0.7 and peak dry matter yield was 1400 and 1100 kg/ha for the grazed and nongrazed pastures, respectively. ET differed only from about June 17 to July 5. Regression analysis showed that ET rate was 3.3 and 3.6 mm/d for the nongrazed and grazed pastures, respectively. Large differences were present between the two pastures for CO_2 fluxes. Flux differences were present from about June 1 to July 5. Regression analysis indicated that CO_2 fluxes were 4.9 and 14.8 g/m^2/d for the nongrazed and grazed pastures, respectively. Soil water content was slightly greater through the season for the nongrazed compared to the grazed pastures. The large differences present in CO_2 flux were probably due to the greater dry matter and LAI for the grazed than the nongrazed or perhaps a grazing effect may have been a contributing factor.

Future Plans: This study is included in the ARS Rangeland Carbon Balance Study and will be continued for several more years.

Publications:

A. B. Frank and A. Bauer. 1996. Temperature, Nitrogen, and Carbon Dioxide Effects on Spring Wheat Development and Spikelet Numbers. Crop Sci. 36:659-665.

IMPACT OF DECADAL PRECIPITATION FLUCTUATIONS ON WATERSHED RUNOFF

Principle Scientist: Jurgen Garbrecht and Glenn Fernandez
Cooperating Scientist: None
ARS GCRP: Res. Areas: III; Prog. Elements: C; Obj.: 1; Task: 1.
CRIS Number: 6220-13610-008-00D

Problem: Impact of global climate change at a watershed scale is difficult to estimate because local and regional climatic conditions are not necessarily correlated to global change parameters. The traditional use of environmental models and generated climate data is also hypothetical in nature and needs to be complemented/supported by actual observations of change.

Approach: The use of historical climate data is proposed as an alternative to generated climate data. Sequences of sustained drought and flooding periods are identified and used to represent a drier and wetter climate scenario, respectively. Precipitation and runoff characteristics for each period are determined at the watershed scale from records. Relationships between precipitation and watershed runoff are established and impact of global change is inferred.

Findings: Over 90 years of precipitation data in Southcentral Oklahoma were analyzed. From this data a ten year sustained drought and wet period were identified. Difference in precipitation between these two periods was about 30% and resulted in an increase of up to 200% in mean annual runoff. Seasonality was also a significant factor with spring and fall receiving more rain and summer receiving less, thus exacerbating seasonal trends. The high sensitivity of the runoff to changes in precipitation and the timing and seasonality of precipitation were found to be important factors in the estimation of the impact of climate change on water resources at the watershed scale.

Future Plans: Pending development and approval of El Reno research program: The impact of the change in precipitation between wet and dry periods on water availability for agricultural needs will be estimated. Changes in amount and seasonality in soil moisture will be determined and implications for crop and forage production will be established using water, heat flux and crop models.

Publications: (since Norman, Oklahoma, 1994 meeting)

Fernandez, G. P., and J. Garbrecht. 1994. Rainfall Fluctuations and its Impact on the Runoff of the Little Washita River Watershed. In: Proceedings of 21st Conference on Agricultural and Forest Meteorology, and 11th Conference on Biometeorology and Aerobiology, Sponsored by American Meteorological Society, San Diego, California, p. J11-J14, March 1994.

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UPDATES TO APPENDIX A

Update to Appendix A: ARS/GCRP Program Elements, Objectives and Tasks

Greg Johnson
Research Meteorologist
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June 27, 1996

Program Element A: Climate and Hydrologic Systems

Objective 4. Change **Rationale** to read:

The spatial and temporal distributions of the many meteorological elements that comprise climate are essential factors for a predictive understanding of hydrologic systems and processes. It is therefore important that the variability of these elements be better understood, especially how variability at the watershed-to-basin spatial scale is related to atmospheric controls, and how this variability may be affected by changes in global climate.

Change **Task 1** to read:

Use the long-term, high quality and spatially-dense climate records from various ARS watersheds to examine spatial and temporal variability of precipitation and other weather elements. Develop relationships between these elements (and their variability) and hydrological and ecological processes over a range of scales. (Boise, Coshocton, El Reno, Ft. Collins, Tucson)

Eliminate **Task 2**.

Eliminate **Task 3**.

Change **Task 4** to read:

Spatial and temporal distributions of <u>weather</u> (add) and climate elements......
(Boise and Tucson)

Change locations for **Task 5** to: Boise, El Reno and Tucson.

Objective 5.

Integrate spatial <u>variability</u> (add), spatial dependence, ...

Change **Rationale** to read:

Stochastic weather simulation models are needed for assessing potential changes in local climate, and for providing synthetic data as input to hydrological and biological systems models. These models, commonly referred to as weather generators, need to be enhanced so that they can be used at any location, deliver sequences of weather at high time resolutions, deliver all elements needed for other modeling requirements, represent spatial dependence at various scales and incorporate non-stationarity in the delivered time series.

Eliminate old **Tasks 1 and 2**.

New Tasks:

1. Derive map layers of GEM model parameters using the PRISM model for the entire U.S., and link these in a user-friendly program for computing weather and climate scenarios at any location, at a targeted spatial resolution of 2 km. (Boise)

2. Develop methods of disaggregating daily values into, or independently generating, high time resolution values of all weather elements. (Boise, Cochocton, Florence, Ft. Collins)

3. Incorporate all weather elements necessary for other modeling requirements into GEM model structure so that these elements (such as dewpoint and wind speed) are generated simultaneously with other elements (such as precipitation and temperature). (Boise, Florence, Temple)

4. Investigate GEM model parameter dependence on large-scale atmospheric forcings, such as ENSO, sea surface temperatures and indices of atmospheric patterns, and incorporate these forcings into the GEM model so that natural variability and non-stationarity effects are expressed correctly in GEM model output. (Boise, Coshocton, Ft. Collins, Temple, Tucson)

5. Develop methods of representing spatial dependence at various scales in stochastic models. (Boise, Coshocton, Ft. Collins, Temple, Tucson)

Changes to list of tasks for Ecosystem group of ARS scientists working on Global Climate Change

Additions and amendments are in bold-face thus.
[Deletions are in square brackets thus, with reason following] **Delete - finished**
* Indicates tasks recognized as falling wholly or partly within the responsibility of the Ecosystem group.

Research Area I: Structure and Function
Program Element C: Ecological Systems
Objective 1:
Tasks:
[1. Derive an object-oriented structure for crop models that satisfies the majority of modelers. (Systems Research Lab.-Beltsville and Riverside)] **Delete - finished**

[2. Implement the crop model structure in C++ using simple algorithms for the methods. (Systems Research Lab.-Beltsville and Riverside)] **Delete - finished**

*3. Replace simple crop growth algorithms with methods appropriate for various crops. (**Remote Sensing & Modeling** Lab.-Beltsville)

*4. Add a two-dimensional model of soil physical, chemical and biological processes and modules describing carbon and nitrogen turnover in agricultural soils as they are related to traditional and prospective management practices to 2DSOIL. (**Remote Sensing & Modeling** Lab.-Beltsville)

*5. Develop a quantitative understanding of carbon and nutrient partitioning to various plant tissues. (Auburn, **Remote Sensing & Modeling** Lab.-Beltsville, Phoenix, Raleigh and Riverside)

*6. Determine the causes and consequences of photosynthetic acclimation to elevated CO_2. (Climate Stress Lab.-Beltsville, Gainesville, Raleigh and Urbana)

*7. Develop a quantitative understanding of how respiration rate responds to changes in CO_2 and temperature. (Climate Stress Lab.-Beltsville, Gainesville and Riverside)

*8. Determine the effects of elevated CO_2, and its interaction with other environmental variables, on the growth, water use, yield, etc. of major crop species, thereby adding to the knowledge base needed to develop and validate crop models. (Auburn, Gainesville, Phoenix, Raleigh, Riverside, Temple and W. Lafayette)

***9. Incorporate stomatal functions into the soil-vegetation-atmosphere transfer model. (Climate Stress Lab.-Beltsville, Raleigh and W. Lafayette)**

Objective 2:
Tasks:
*1. Determine the role of genetic variability in the responses of rangeland plants to CO_2, and its importance to plant populations and ecosystem species interactions. (Temple)

*2. Measure and model nutrient and dry mater partitioning, tittering, root architecture and geometry, limits to potential growth, and over-wintering characteristics of rangeland grasses as affected by carbon, nitrogen and water status of the plants. (Gainesville, Woodward **and Miles City**)

*3. Determine if nitrogen limitations will prevent rangeland plants from responding to high CO_2 with increased production. (Cheyenne and Temple)

*4. Determine if differences in response to high CO_2 among C4 species are related to differences in photosynthetic pathways or differences in growth forms. (Cheyenne)

*5. Determine the long-term linkage between nitrogen availability and increased CO_2 in natural ecosystems. (Cheyenne and Temple)

*6. Determine the long-term linkage between temperature and increased CO_2 in natural ecosystems. (Cheyenne)

*7. Determine if generalizations about plant responses to climate change can be based on functional groups such as C3, C4, annual, perennial, woody, and herbaceous, etc. plants. (Climate Stress Lab.-Beltsville, Cheyenne and Temple)

*8. Develop methods for assessing long-term direct effects of increased CO_2 on long-lived perennials and stands of perennials. (Phoenix)

*9. Develop models for plant species of differing physiognomy and functional classification (trees, weeds, grasses, broad-leaved plants, shrubs, etc.). (Temple and W. Lafayette)

[10. Develop methods for using data on responses of individual plant species to high CO_2 to predict how those species will compete with others that respond differently. (Cheyenne and Temple)] **Delete - too expensive**

Objective 3:
Tasks:
*1. Measure and model stomatal responses to plant water stress. (Climate Stress Lab.-Beltsville, Gainesville, Phoenix and Woodward)

*2. Measure and model stomatal function, Rubisco activity and gas exchange as functions of CO_2 and light intensity. (**Climate Stress Lab.-Beltsville**, Gainesville, Phoenix and Raleigh)

*3. Determine the causes and consequences of photosynthetic acclimation to high CO_2. (Climate Stress Lab.-Beltsville, Cheyenne, Gainesville, Phoenix, Raleigh and Urbana)

*4. Collect data sets for modeling photosynthesis and transpiration as the diffusion of gases in a matrix of mesophyll cells. (Urbana)

[5. Parameterize 2DLEAF for soybean and tomato and validate the model using existing data sets. (Systems Research Lab. - Beltsville)] **Delete - finished**

[6. Use 2DLEAF to compare available models of leaf biochemistry. (Systems Research Lab. - Beltsville)] **Delete - finished**

*7. Develop a sub-model of CO_2 and O_2 transfer between intercellular space and chloroplasts for

use in 2DLEAF. (**Remote Sensing & Modeling** Lab.-Beltsville)
*8. Develop a sub-model of the regulation of stomatal aperture, for use in 2DLEAF. (**Remote Sensing & Modeling** Lab.-Beltsville)

*9. Measure the effects of elevated CO_2 on gene expression of photosynthetic proteins. (Phoenix)

10. Adapt energy-balance feedback mechanisms into crop models for improvement of effects of foliage temperature on evapotranspiration, photosynthesis and respiration. (Gainesville)

11. Analyze photosynthesis in plants grown at different levels of UV-B radiation and determine the impact of enhanced UV-B radiation on photosynthetic performance. (Urbana)

***13. Evaluate and study the interaction of elevated CO_2 and temperature on C partitioning in C3 and C4 plants. (Gainesville and Temple)**

Objective 4:
Tasks:
*1. Investigate interactive effects of CO_2 and O_3 concentrations on growth and yield of major crop species, and determine genetic variability in the response (Raleigh)

*2. Obtain physiological response data for O_3 and elevated CO_2 environments to be used in development of plant growth models. (Raleigh)

*3. Obtain data on the rates of photosynthesis and respiration, and shoot and root growth and development at various CO_2 and salinity concentrations. (Riverside)

*4. Develop a model of wheat growth that responds to various CO_2 and soil salinity concentrations. (Riverside)

*5. Determine if elevated CO_2 and/or O_3 concentrations affect crop susceptibility to pests and pathogens. (Raleigh)

Program Element D: Integrated Systems
Objective I
Tasks
*1. Validate the soil-vegetation-atmosphere transfer model. (Climate Stress and Hydrology Labs.-Beltsville)

*2. Determine the rates at which carbon fixed by plants can be incorporated into organic soil carbon and inorganic soil carbonates. (Phoenix and Temple)

3. Incorporate nutrient cycling and C sequestration with water balance, hydrology and plant species productivity and diversity. (Columbus and Phoenix)

4. Link gas fluxes and radiation forcing with weather, water balance, hydrology, and plant species productivity and diversity. (Hydrology Lab.-Beltsville, Phoenix, and Tucson)

5. Promote inclusion of models into the Modular Modeling System (MMS) format to facilitate interaction between and within groups. (Great Plains Systems and TERRA Ft. Collins, Tucson)

6. Develop the ability to model the effects of C02 changes on plant composition of natural landscapes and the resulting feedback of the changing vegetation on hydrology and water supply. (Boise)

7. Develop the ability to model landscapescale drought, and predict how changes in the frequency of drought will influence regional insect pest outbreaks. (Bozeman)

8. Develop the technology required to model aquatic and riparian ecosystems, including streams, wetlands, and impoundments associated with agricultural watersheds. (Durant)

Research Area II: Socioeconomic Driving Froces
Program Element B: Technology Transfer
Objective 1:
Tasks:

*1. Establish an Internet site for archiving validated models.and data sets ina standard format. (**Remote Sensing & Modeling Lab.**-Beltsville)

2. Establish an Internet site for the Semi-Arid Land Surface Atmosphere (SALSA) Program for coordination of multidisciplinary activities and data on the San Pedro Basin. (Tucson)

Research Area III: Impacts and Adaptation
Program Element A: Impacts of and adaptation to global change in the environment
Objective 2:
Tasks:

[1. Incorporate stomatal functions into the soil-vegetation-atmosphere transfer model. (Climate Stress Lab.-Beltsville, Raleigh and W. Lafayette)] **Delete - moved to I,C,1**

*2. Determine the effect of changes in atmospheric CO_2 concentration on ecosystem vegetation change and soil organic matter. (Mandan and Temple)

[3. Evaluate and study the interaction of elevated CO_2 and temperature on C partitioning in C3 and C4 plants. (Gainesville and Temple)] **Delete - moved to I,C,3**

*4. Use 2DSOIL to evaluate the short-term and long-term effects of management practices on the fate and accumulation of organic nitrogen. and carbon in soils under various management practices in a CO_2-enriched environment. (**Remote Sensing & Modeling** Lab. - Beltsville and Raleigh)

*5. Validate software for making yield predictions on large areas (county and state levels) from plot-level crop models and use it to predict crops' and farmers' responses to climate change. (**Remote Sensing & Modeling** Lab.-Beltsville)

[6. Measure and model stomatal responses to plant water stress. (Phoenix)] **Delete - duplicate of I,C,3,1**

[7. Measure and model stomatal functions, Rubisco activity and gas exchange as functions of CO_2 and light intensity. (Phoenix)] **Delete - duplicate of I,C,3,2**

[8. Determine the causes and consequences of photosynthetic acclimation to higher CO_2. (Phoenix)] **Delete - duplicate of I,C,3,3**

[9. Measure the effects of elevated CO_2 and gene expression of photosynthetic proteins. (Phoenix)] **Delete - duplicate of I,C,3,9**

[10. Incorporate energy-balance feedback into crop models. (Gainesville)] **Delete - duplicates part of I,C,3,10**

Objective 3:
Tasks:
*1. Determine how high CO_2 affects the establishment and survival of plants, especially shrubs, invading grassland. (Temple)

*2. Determine effects of climate change on forage quality. ([Climate Stress Lab.-Beltsville and] **Delete - CSL part finished** Gainesville)

*3. Evaluate the effects of grazing on carbon assimilation and storage in grasslands. (Cheyenne)

*4. Evaluate the impacts of land use on nitrogen cycling in the Sagebrush Steppe. (Burns)

Objective 4:
Tasks:
*1. Determine whether or not increased productivity in high CO_2 is related to changes in species composition, and whether the increases in soil carbon content are caused by increased root mass, changed litter quality, or root exudation. (Temple and Auburn)

*2. Determine the effects of elevated atmospheric CO_2 concentrations on soil carbon sequestration using free-air CO_2 enrichment in combination with soil carbon isotopic analyses and measurements of gas exchange and root and residue biomass supplies. (Phoenix)

Objective 5:
Tasks:
[l . Determine the extent to which the distribution of pests and diseases will prevent the movement of crop cultivars from one area to another because the crops have no resistance to the new pests and diseases they will encounter. (Auburn and Raleigh)] **Delete - No work actually being done on this**

Research Area IV: Mitigation and Enhancement
Program Element A: Mitiation of detrimental effects and enhancements of positive effects of global change
Objective 1:
Tasks:
1. Assemble, interpret and distribute results of model classifications, model comparisons, hydrologic response, and climate change scenarios for water resource managers. (Hydrology Lab. - Beltsville, Boise, Tucson, and W. Lafayette)

2. Develop techniques to estimate ancillary responses to climate induced changes in soil water, stream flow and other fluxes to assist land and water resource managers. Evaluate effects on stream channels, water quality, erosion, sediment yield, reservoir siltation rates, and revegetation. (Hydrology Lab. - Beltsville, Boise, Durant, Great Plains Systems - Ft. Collins, Temple, Tucson, and W. Lafayette)

*3. Develop decision support systems to assist land and water resource managersin selecting the best management strategy from among feasibler mitigation alternatives. (Boise, Prosser, and Tucson)

4. Long-range forecast model output (including Climate Analysis Center products and GCMs) will be incorporated into decision support systems as a means of evaluating their potential for planning and mitigation. (Boise, and Tucson)

Objective 2:
Tasks:
*1. Evaluate and study enhanced carbon sequestration by better crop residue management. (Akron, Auburn, Durant, Lincoln, Morris, Sidney, St. Paul and Temple)

*2. Determine the effects of elevated atmospheric CO_2 concentrations on soil carbon sequestration using free-air CO_2 enrichment in combination with soil carbon isotopic analyses and measurements of gas exchange and root and residue biomass supplies. (Phoenix) **identical to III,A,4,2. Both needed?**

Objective 3:
Tasks:
1. Develop water-table-control management practices to periodically aerate the soil to reduce methane emissions. (Gainesville)

2. Develop organic matter management practices to decrease methane emissions from rice fields. (Gainesville)

3. Determine cultivar or physiological factors that govern methane emissions from rice. (Gainesville)

Objective 4:
Tasks:
1. Develop soil heating stress methods through enhanced soil solarization techniques. (Gainesville)

2 Develop oxygen stress methods through off-season soil flooding of high water table soils that are drained for agriculture. (Gainesville)

3. Develop biological control technologies for plant pathogen. (Fort Pierce)

4. Assess alternative chemical control strategies. (Fort Pierce, Fresno and Riverside)

Program Element B:
Objective 1:
Tasks:
1. Implement demonstration project in Florida vegetable production systems. (Fort Pierce)

2. Implement demonstration project in California vegetable production systems. (Fresno)

United States Department of Agriculture

Agricultural Research Service

Southern Plains Area

June 22, 1996

SUBJECT: Global Change Research Program

TO: Dr. Rango, Dr. Cooley and Dr. Mayeux

FROM: Jurgen Garbrecht and Patrick Starks

As you are aware the National Agricultural Water Quality Laboratory located in Durant, Oklahoma, is being merged with the Grazinglands Research Lab in El Reno, Oklahoma. Therefore, the Durant location no longer exists and all references to **Durant** in Appendix A, Volume II of the 1996 Global Change document are no longer correct.

We expect the El Reno Grazingland Laboratory to remain involved in the Global Change Research Program. However, the new El Reno program is presently being redefined and specific project level contributions to the Global Change Program cannot be identified.

An educated guess on our part suggest that the El Reno program may address issues relevant to:

Research Area I;	Program Element A (Climate and Hydrologic Systems).
Research Area III;	Program Element A (Impacts of and Adaptation to Global Change)
	Program Element C (Risk Assessment)
Research Area IV;	Program Element A (Mitigation of Detrimental Effects and Enhancement of Positive Effects of Global Change)

We know this is not hard information for you to work with, but this is all we can give you at this time. If you have any questions, do not hesitate to call us.

cc: Dr. J. Quisenberry

United States Department of Agriculture
Agricultural Research Service
Southern Plains Area

National Agricultural Water Quality Lab
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June 24, 1996

Dr. Herman Mayeux
USDA-ARS-NPA
Bldg. 005, Room 325
BARC-West
Beltsville, MD 20705

Dear Dr. Mayeux:

As you are aware the National Agricultural Water Quality Laboratory located in Durant, Oklahoma, is being merged with the Grazinglands Research Lab in El Reno, Oklahoma. As a result of this merger, the El Reno research program is being redefined. Therefore, we are unable to submit at this time a specific proposal for funding under the global change program. However, we expect to address issues relating to the interaction of climate fluctuations and grazingland productivity. This interdisciplinary topic should be of great interest to the global change program. We would greatly appreciate the opportunity to submit a late proposal after the EL Reno program has been established and research directions have been defined.

Sincerely

Pat Starks

Jurgen Garbrecht and Patrick Starks

cc.: Jerry
Al Rango K Cooley